

**Does forage enrichment promote increased
activity in captive capuchin
monkeys (*Cebus apella*)?**

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Figure 1. Juvenile female capuchin (*Cebus apella*)



Figure 2. Sub-adult male capuchin (*Cebus apella*)

Executive Summary

In their native habitat of Central and South America, capuchin monkeys (*Cebus*) spend 45% to 55% of their day foraging and a further 20% travelling. Once these monkeys are introduced into captive environments their diets are selective, seasonal and presented to them by their keepers. The captive environment often leads to various behavioural abnormalities and compensatory behaviours or stereotypies. To address this issue, environmental enrichment can be employed to reduce, cure or prevent such an occurrence. Enrichment can reduce stress, while increasing animal well-being and health in captivity. Despite previous work a better understanding of enrichment, for most neo-tropical primate species, is necessary, in order to improve their captive lifestyles.

Feeding of captive primates is more complex than providing a balanced nutritional diet as it must also meet their ethological needs. The manipulation of the presentation of the diet has been shown to significantly decrease the incidence of resting, while significantly increasing the incidence of playing, grooming, foraging and manual manipulation of dietary items.

Eleven capuchin monkeys were presented with four different feeding treatments (i.e. cut food presented in bowls, cut food presented around the enclosure, uncut food presented around the enclosure and novel feeding devices presented around the enclosure) from December 2007 until May 2008. At the start of every month one of three feeding treatments was introduced with the cut food in bowls feeding treatment interleaved between the treatments.

The different feeding treatments required the monkeys to search for their food, break-up their food into manageable sizes, and obtain food in touch-, tool- and manipulative-dependent methods in order to allow the monkeys an opportunity to display increased activity more in line with their wild conspecifics.

The capuchins displayed a period of intense foraging directly following feeding. This period significantly increased (from 44 to 121 min.), along with foraging events and the proportion of time spent foraging, which was more in line with their wild conspecifics. In addition, the frequency of occurrence and the proportion of time spent on locomotion and resting was shown to decrease. Also, abnormal behaviours ceased to occur during the study.

Environmental enrichment is a useful tool for providing stimulation, redistributing activity levels more in line with wild conspecifics and to combat abnormal and compensatory behaviours.

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1. General Introduction

1.1. Introduction

Capuchin monkeys (*Cebus* spp.) are extremely popular in zoos; their social attitudes and manipulative skills are much appreciated by visitors (Fragaszy *et al.* 2004). Capuchins are also widely popular as pets and exhibits as they are easy to keep in good health, active, highly trainable, interesting to zoologists in their own habitat, and kept by medical and behavioural scientists for reasons of suitability as well as for their special characteristics (e.g. manipulative propensities) (Fragaszy *et al.* 2004).

Cebus apella are one of the most common capuchins kept in captivity, particularly for biomedical research (Fragaszy *et al.* 2004), presumably due to the extent of their natural range, abundance, threat status and their availability. Data obtained from the International Species Information System (ISIS; 09 July, 2008) indicates that the total number of *Cebus apella* held in zoos around the world consists of eight subspecies in thirteen categories, totalling 830 individuals (Appendix 1). The 830 individuals were made up of 383 males, 344 females, 68 unknowns and 35 juveniles under one year old. However, these 830 individuals are only consistent of the zoos that are monitored by ISIS of which the population in this study did not exist. The data obtained from ISIS also indicates that *Cebus apella* is the most commonly kept species of *Cebus* in zoos around the world.

1.2. Willowbank's *Cebus apella* population

A population of 11 extant capuchin monkeys (*Cebus apella*) was the subject of this study. The population consisted of two adult males, six adult females, one sub-adult male, and a juvenile male and female (see Table 1.2). The subjects ranged in age from one to 18 years. All subjects were born in captivity. Within the first month of this experiment an adult female gave birth to still-born twins and days later she died of a uterine infection, taking the population down to 10 individuals. The initial capuchin population was established at Willowbank in 1975. According to Willowbank Wildlife Reserve's records, the entire population originated from an old male (Sundance) and a 12 year old female (Cappy) (Appendix 2). Since these initial two monkeys, only one other (Hope) has been introduced as new genetic stock. However, Hope along with her mate (Survivor) and the resulting offspring (Lucky and Sunny) were sent to Thailand. Therefore, genetic stock has been lost and inbreeding has occurred in every generation with the current alpha/oldest male (Mr Flick) a first generation inbred. Mr Flick was recorded as fathering Grumpy to an unknown female and was also responsible for the pregnant female whom later required a caesarean which resulted in a juvenile fatality. The youngest juvenile male (Johnny) was the son of Pam, and probably Mr Flick. All other current genetic relations are unknown/ unverified.

1.3. Conservation status and categorisation

Capuchin monkeys are members of the Cebidae family which also includes marmosets, tamarins (Callitrichinae), and squirrel monkeys (Saimiriinae). They are classified as one genus, *Cebus*, with a debatable number of species and subspecies. The International Union for Conservation of Nature (IUCN; 2007) recognises seven species and 20 subspecies

(Appendix 3), although the United Nations Environmental Programme – World Conservation Monitoring Centre (UNEP-WCMC; 2008) and Groves (2005) each recognise eight species (of which only five are recognised by IUCN (2007)). Groves (2005) also recognises 19 subspecies of which only seven are recognised by IUCN (2007). A new species thought to comprise of only 18 individuals was described and named in 2006 (Mendes Pontes *et al.* 2006) and currently does not appear to be in any taxonomic list. In some instances, it appears that the same subspecies and naming authority occur under different species in different publications, suggesting that reclassification has been made in some publications and some subspecies have been raised to species level.

The conservation status of species and subspecies under the genus *Cebus*, have been ranked from ‘Least Concern’ to ‘Critically Endangered’ by IUCN (2007). The Brown-capped capuchin (*Cebus apella* ssp. *apella*) has been ranked as a ‘Least Concern’ species by IUCN as it is wide-ranging and an adaptable taxon. *Cebus apella* is one of the most widely ranging species of the New World monkeys (Izawa, 1980; Ross & Giller, 1988) and is found throughout Amazonia and as far south as Central Bolivia, Paraguay, Northern Argentina, and Central and Eastern Brazil (Ross & Giller, 1988) (Figure 1.). *Cebus apella* is described by Oppenheimer & Oppenheimer (1973) as morphologically and behaviourally distinct from other *Cebus* species and the *Cebus* genus fits into category IV of the Eisenberg *et al.* (1972) classification scheme of primate social behaviour, i.e. frugivore-omnivore, semi-terrestrial, age-graded male troop, with a dominance hierarchy based on age.



Figure 1. Geographic distribution of *Cebus apella* in South America (shaded area), noting the subspecies (*C. a. margaritae*) on the island of margarita (modified from Fragaszy *et al.* 2004).

1.4. Capuchin ecology

The approximate mass of a wild adult *C. apella* is 2.5-4.0 kg (Boinski *et al.*, 1999; Fragaszy *et al.*, 2004; Nagle & Denari, 1982), depending upon gender, age, health and environment. However, within captive environments capuchins are known to have a mass above six kilograms, and also have a much extended life expectancy, of more than 50 years (Fragaszy *et al.*, 2004). Capuchins are physically different from other New World monkeys (Platyrrhines) in that they have robust jaw and dental structures, large brains (in relation to their body size), and semi-prehensile tails. Additionally, their hands have strong grips, some degree of opposability between the thumb and other digits, and somewhat independent finger movements (Fragaszy *et al.* 2004). Capuchins most commonly use quadrupedal locomotion, although in captivity, they are known to turn to bipedalism for short bursts when their forelimbs are occupied holding relatively heavy objects (in relation to body mass), potentially using their tails as a balance (Dutton pers. obs., 2008).

Capuchins are opportunistic omnivores with their diet consisting of a wide array of plant and animal materials from fruits and leaves to invertebrates and birds (Baldwin & Baldwin, 1977; Hayes, 1990). They also commonly employ complex skills in obtaining food. For instance, they have been observed to incorporate tools in processing particular dietary items, such as palm-nuts (Izawa & Mizuno, 1977; Struhsaker & Leland, 1977), and exclusively use the sense of touch to recognise and then obtain non-visual food items (Izawa, 1979).

The home range size of *Cebus apella* is about 90 ha which is similar to other closely related species, e.g. *C. capucinus* and *C. albifrons* (Fragaszy *et al.* 2004). Group sizes differ considerably between closely related species (Defler, 1979), however, *Cebus apella* is reported as having group sizes commonly consisting of 12-24 individuals (Fragaszy *et al.*, 2004), whilst, *C. albifrons* groups have been observed with up to 50 individuals (Defler, 1979).

Cebus apella reach sexual maturity at four to five years of age (Nagle & Denari, 1982). Adult males, whether maintained in outdoor enclosures or caged in controlled environmental conditions, showed no definite breeding season (Nagle & Denari, 1982). *C. apella* birth peak varies considerably with geographic range. In Argentina, births peak from October to February, while in Columbia births peak from February to May (Di Bitetti & Janson, 2000). In a captive non-neotropical situation, as in New Zealand, *Cebus apella* population births were not defined to a season; births were observed from December through to June (Dutton, pers. obs.) and expected to be year round.

Cebus apella females have a menstrual cycle of 19 – 22 days (Fragaszy, 2005; Nagle & Denari, 1982) with a mean length of menstruation of 2.8 ± 0.4 days (Nagle & Denari, 1982). Gestation lasts from 22 to 23 weeks, followed by 22 weeks without menstruation during nursing if the mother rears the baby (Fragaszy, 2005; Nagle & Denari, 1982), or about seven to eight weeks without menstruation if she loses the baby (Fragaszy, 2005).

Female tufted capuchins (*Cebus apella*) display their interest in mating using a rich and varied behavioural repertoire consisting of facial expressions, vocalizations, gestures, and body postures (Fragaszy, 2005). In general, the female actively follows a target male, which, in most cases, is the dominant male in her group and directs most if not all of her solicitations toward this target male (Fragaszy, 2005; Phillips *et al.* 1994). Initially (for

hours and/or days), the sought-after male does not reciprocate and tends to avoid the female by leaving as soon as she approaches him (Dutton pers.obs., 2008; Fragaszy, 2005; Phillips *et al.* 1994). Later, the target male starts to respond to the female's solicitations with behaviours similar to hers (Dutton pers. obs., 2008; Fragaszy, 2005). At this point, mutual sexual interest becomes evident and mating occurs (Fragaszy, 2005; Phillips *et al.* 1994).

Capuchins are also known to partake in self-care behaviours such as urine washing and anointing. Roeder & Anderson (1990) and Carosi & Rosofsky (1999) both conclude that the most prominent function of urine washing is thermoregulation. Alternatively, Miller *et al.* (2007) concludes that urine washing does not function in thermoregulation or in territorial communication but suggests that it may be associated with sexual encounters and receiving aggression. Anointing is observed as rubbing of pungent and irritating materials on the fur with a functional consequence of bactericidal or insect repellent (Baker, 1996). In a captive environment these materials are infrequently available, however *C. apella* has been observed using garlic and common ground beetles (Carabidae) (Dutton pers. obs.).

Capuchins are known to be prey items of several large carnivores, such as jaguars, pumas, jaguarondis, coyotes, tayras, venomous and constricting snakes, caimans and crocodiles, and raptors, such as eagles, hawks and owls (Fragaszy *et al.*, 2004). Other threats to capuchin survival include the bush-meat trade, live capture for export and trade and destruction of habitat by encroaching civilisation (Fragaszy *et al.* 2004).

Capuchins are potentially important as secondary pollinators of some vine and tree species (Prance, 1980; Sussan & Raven, 1978) and also important as seed dispersal agents (Rowell & Mitchell, 1991; Zhang & Wang, 1995)

1.5. Captive versus free-living behaviour

In their native habitat of Central and South America, capuchin monkeys (*Cebus*) spend 45% to 55% of their day foraging and a further 20% travelling (Baldwin & Baldwin, 1977; Hayes, 1990). However, *Cebus apella* have been shown to spend up to 93% of their time travelling, feeding and foraging, with resting periods occupying as little as 4% (Izawa, 1980).

Ross and Giller (1988) concluded that a captive *C. apella* population spent around 50% of its active time foraging and eating, 7-10% of this time walking and around 30% of the total time inactive. In other captive *Cebus* populations, animals were active for less than 40% of their waking hours and feeding activity was seen over about 25% of the time (Bernstein, 1965). Similar reductions in foraging activity have also been documented in other primates. Free ranging baboons provisioned via a garbage dump were described by Altmann & Muruthi (1988) to spend approximately 20% of their time foraging, whereas their more rural counterparts spent closer to 60% of their time foraging for food. This pattern also emerged in rhesus monkeys of northwest Pakistan where foraging ranged from approximately 16% in urban areas to nearly 50% in rural areas (Goldstein & Richard, 1989).

When compared to wild conspecifics many other mammals in captive environments also show reductions in activity. Well documented examples include African and Asian elephants (Stoinski *et al.* 2000; Wiedenmayer, 1998), captive felids (cheetah, cougar,

jaguar, lion, ocelot and tiger; Skibieli *et al.* 2007), brown bears (Grandia *et al.* 2001) and pigs (Young, 1997; Young & Lawrence, 1996). Young (1997) identified that a domestic sow will forage for 50% of their day in a natural environment, but when trough-fed, this is reduced to 10-20 minutes.

Maned wolves in the wild may spend an entire day or night exploring home ranges for any changes. However, in captivity the animal's home area is comparatively small and static and it only takes a few minutes to inspect a single object placed in the enclosure (Cummings *et al.*, 2007).

Free-ranging elephants spend the largest proportion of their time foraging, estimated at approximately 16 hours per day (Shepherdson, 1999; Stoinski *et al.*, 2007). In captivity, elephant diets are more spatially and temporally concentrated and contain much less variety, resulting in substantially less time spent foraging and processing (Wiedenmayer, 1998; Shepherdson, 1999).

Once monkeys are introduced into captive environments their diets become selective (restricted due to producer or country availability) and seasonal (shelf or stock availability). Also, their diet is presented within a defined environment rather than them having to obtain it from various localities and sources.

Selectivity, seasonality and presentation of diet in captivity can lead to various stress-related behavioural abnormalities and compensatory behaviours or stereotypies (e.g. self-directed behaviour (Manson & Perry, 2000), excessive grooming, the consumption of non-dietary items, pacing, back-flipping, self-biting, coprophagy, regurgitation, reingestion, faecal smearing (Lutz & Novak, 2005), spinning, rocking (Lutz & Novak, 2005; Wells *et al.*, 2006), cage strumming and licking (Bellanca & Crockett, 2002) hyperaggressiveness, hypersexuality, inappropriate sexual behaviour (copulating attempts with objects), abnormal postures, low socialization, auto-mutilation, stereotyped behaviours and overt expression of some normal behaviours out of context (Boere, 2001)) that subsequently impact on the conservation of the species, education and entertainment of the public and the opportunity for scientific research.

Stereotypies are often seen in environments that seem sub-optimal. They are physically or temporally associated with lack of stimulation, or events such as acute stressors or the expected arrival of food (Mason, 1991; Mallapur & Choudhury, 2003). These sub-optimal environments may involve chronic conflict and frustration and hence stress, particularly if uncontrollable or unpredictable (Mason, 1991). Environmental enrichment, well-being and stress are associated concepts regarding techniques, physiology and behaviour aspects. Enrichment can reduce stress, while increasing animal well-being and health in captivity (Boere, 2001). A study by Boinski *et al.* (1999) found that foraging enrichment positively affected behavioural and physiological responses to stress and enhanced psychological well-being in brown capuchins which were housed singly.

1.6. Enrichment

The roles of the modern zoo/wildlife reserve are to conserve species, educate people, entertain the public and provide opportunity for scientific research (Tudge, 1992). The well-being of the animals is essential in providing these four roles.

Environmental enrichment is commonly advocated as an effective method to improve psychological well-being of nonhuman primates and other mammals in captivity (Boinski *et al.* 1999). The ultimate goals of environmental enrichment are to promote species-typical behaviour and eliminate abnormal behaviour.

There are three clear hypotheses about utilising enrichment devices for encouraging species-typical behaviour. The first hypothesis, the “usage” hypothesis, is based on the premise that using an enrichment device requires species-typical behaviour (Lutz & Novak, 2005). Predictions can be made for different kinds of enrichment. For example, when monkeys are provided with foraging devices, foraging should increase and when monkeys are provided social contact, socialisation should increase.

A second hypothesis, the “normalised repertoire” hypothesis, predicts that the employment of enrichment helps normalise other aspects of the behavioural repertoire (Lutz & Novak, 2005). For example, the employment of a foraging device is predicted to alter other behaviours, through time budgets, in addition to those directly related to the enrichment device. The value of testing the normalised repertoire hypothesis is that it assesses the overall impact of enrichment on the animal (Lutz & Novak, 2005).

A third hypothesis of environmental enrichment is to reduce the occurrence of abnormal behaviour. The third hypothesis can be split into two premises: whether currently existing enrichment lowers levels of abnormal behaviour, and whether it prevents the behaviour (Lutz & Novak, 2005).

Enrichment strategies can be divided into two general categories: providing the animals with inanimate forms of enrichment, and providing the animals with social contact (Lutz & Novak, 2005). Inanimate enrichment can be further divided into those that require some physical activity on the part of the animal (active enrichment) and those that provide only passive kinds of stimulation (Lutz & Novak 2005).

A major component in the welfare of organisms is an appropriate feeding programme. For captive primates we must consider a balanced nutritional diet and how that diet is presented, to incorporate the four roles of the modern zoo/wildlife reserve (Young, 1997). Feeding of captive primates is more complex than providing a balanced nutritional diet; the diet should consist of a series of procedures that improve the quality of life of the captive animals by meeting their ethological needs (Boere, 2001).

Forage enrichment is an environmental enhancement of the method in which food is presented. For primates, it can be as simple as scattering food around their enclosure, or as sophisticated as using artificial feeding devices to encourage a time budget closer to that displayed by a species wild counterpart. An important consequence of forage enrichment is the reduction or elimination of abnormal behaviour that is thought to be indicative of reduced welfare status (Mason, 1991).

Ex situ conservation programs should be concerned with maintaining wild species-typical behaviours. The presentation of the diet is one particular area where application of ingenuity can be exercised to stimulate animals without compromising their health. Manipulating presentation of the diet has been shown to significantly decrease the incidence of resting (Maloney, et al. 2006; Sommerfeld, et al. 2005; Voelkl, et al. 2001), significantly increase the incidence of playing and grooming (Maloney, et al. 2006),

increase foraging (Kerridge, 2005) and increase the manual manipulation of dietary items (Kerridge, 2005).

Several studies of primates have focussed on providing captive species with foraging enrichment (e.g. Anderson & Chamove, 1984; Baker, 1997; Bayne, et al., 1992; Boinski et al., 1999; Crockett et al., 2001; Hayes, 1990; Ludes & Anderson, 1996; Maloney, et al., 2006; Sommerfeld, et al., 2005; Voelkl, et al., 2001). Anderson & Chamove (1984) found that woodchip and woodwool allowed a group of stump-tailed macaques (*Macaca arctoides*) to demonstrate compensatory behaviours, such as reductions in play, aggression, manipulation of the environment, and self-aggression. Voelkl, et al. (2001) found that a mealworm dispenser resulted in a significant increase in the amount of time foraging and may have raised vigilance in common marmosets (*Callithrix jacchus*). Also, foraging rates of 30% were observed in captive group-housed terrestrial macaques given grain in woodchips and 50% for individually housed macaques given artificial turf (Bayne et al. 1992; Chamove & Scott, 2005). By providing captive capuchins (*Cebus capucinus*) with polyvinylchloride (PVC) pipe feeder boxes containing their daily feed, Hayes (1990) was able to encourage increased feeding times and greater expression of species-typical foraging behaviour.

A group of hamadryas baboons (*Papio hamadryas hamadryas*) implicated in a monopolised food source were observed to redirect and increase foraging behaviours elsewhere in their enclosure (Jones & Pillay, 2004). Also, when a captive group of ring-tailed lemurs (*Lemur catta*) were presented with browse in food boxes and the food boxes were spatially separated, activity levels increased and unwanted behaviours (pirating) decreased (Dishman *et al.*, In press). Similarly, captive-bred black and white ruffed lemurs (*Varecia variegata variegata*) were encouraged by Britt (1998) to spend a similar amount of time feeding as their wild conspecifics when food accessibility was reduced. Britt (1998) presented food on the rooftop of a cage or suspended in wire baskets from trees and shrubs and encouraged similar relative use of suspensory feeding postures to that observed in the wild, reduced terrestrial feeding and increased the time spent feeding from 15% to 20.5%. Csatádi *et al.* (2008) found that when a group of captive bonobos (*Pan paniscus*) were provided with novel enrichments, the general activity increased. Simultaneously, these novel behavioural challenges significantly decreased the frequency of unwanted behaviours.

Although some important studies on enrichment exist (e.g. Anderson & Chamove, 1984; Baker, 1997; Boinski et al., 1999; Ludes & Anderson, 1996; Hayes, 1990), a better understanding, for most neotropical species, is still necessary (Boere, 2001). The main factors considered in enrichment programs include hygiene, space and complexity, diet, social composition and personnel involved (Boere, 2001).

A population of 11 capuchin monkeys (*Cebus apella*), all born in captivity, reside in an outdoor enclosure made of wire mesh and wooden beams at Willowbank Wildlife Reserve in Christchurch, New Zealand. They range in age from one to 18 years and until recently they had been fed using bowls filled with a variety of cut food items. This may have caused malnutrition of some individuals by guarding of food by others, disproportionate food allocation (with particular reference to desired foods causing poor health through increased weight and poor diet selection), decreased foraging, increased incidence of resting and potentially increase stress-related stereotypies due to the absence of stimuli, such as consistent displacement of food sources.

Six months prior to this study the presentation of the capuchins diet was changed to distributing cut food items throughout their enclosure. This example of enrichment has been shown to significantly decrease the incidence of resting, significantly increase the incidence of playing and grooming, increase foraging and increase the manual manipulation of dietary items (Anderson & Chamove, 1984). Further enhancement of dietary presentation may improve the welfare status (general health at individual and population level, reproductive behaviour, weight, stress, social stability, etc.) of the captive individuals, display behaviours in line with their wild conspecifics and ultimately provide higher observer satisfaction.

1.7. Research objectives

This research investigates a practical problem associated with all zoos and wildlife reserves: that of quality of life of the captive animals. This research will be focussed on a specific population of a species in a unique situation. The intent of this study is to provide a group of 11 captive *Cebus apella* with a variety of forage enrichments to allow the monkeys an opportunity to display increased activity more in line with their wild conspecifics. Research of a captive population will always have logistical limitations, for example, a small sample size or issues of dependence, e.g. autonomous behaviour. However, these may be compensated by little repetition or replication of records and studying of an entire unique population within a large proportion of its environment. However, these conditions are typical of most captive populations and must be regarded as an extreme of the range of environments in which a species can survive and breed (Rowell, 1967). The following hypotheses will be tested about forage enrichment and population activity for this captive non-human primate:

Ho. *There is no effect of the forage enrichment on activity*

H1. *Forage enrichment promotes increased activity (i.e. foraging, locomotion, grooming, and other beneficial behaviours)*

Arising from these hypotheses, five associated research questions were developed:

1. By employing a new method of food presentation, will capuchin activity change?
2. How do the different stages of presentation compare?
3. Are the cut food presented in bowls treatments influenced by the alternating treatments as time progresses?
4. Will behaviour change during periods when the foraging stimuli have been removed?
5. Is foraging activity determined by any alternative factor/s (i.e. temperature, precipitation, visitor numbers or zookeeper)?

Based on the above questions the specific research objectives were:

- To investigate the behaviour of capuchins under the influence of changes in dietary presentation;

- To test the utilisation of the different foraging devices on capuchins;
- To identify determinants of changes in activity.

2. Methods

2.1. Husbandry

The capuchins were housed together in an outdoor enclosure made of wire mesh and wooden beams (Plate 1) at Willowbank Wildlife Reserve in Christchurch. The 17.1 m (length) x 8.2 m (width) x 7.0 m (height) outside area was furnished with several logs and branches, numerous ropes and a cement pond with a constant flow for drinking water (Plate 2). Access to a 3.6 m (length) x 3.0 m (width) x 2.2 m (height) shelter and a 2.9 m (length) x 3.0 m (width) x 2.2 m (height) night den was constantly available.

The diet (Appendix 4) was split into morning (10 – 11 am) and afternoon feeding sessions (3 – 4 pm), each of which consisted of six apples, eight bananas, seven slices of bread (any available type), two carrots, 100 g of cheese, four boiled eggs, 35 grapes, 150 g cooked rice (cooked with tea bags for tannins and honey for a sweetener), ¼ cup sultanas, one bunch of spinach/celery, four kiwifruit and three cooked potatoes.

When bread was not available, it was substituted for one kilogram of Lex Primate Pellets (Dunstan Animal Feeds, Camtech Nutrition Ltd, Hamilton NZ) (Appendix 5). Cleaning of the enclosure occurred daily (prior to morning feeding session) with fresh sawdust spread on the ground and removal of faeces and any remaining food items.



Plate 1: The outdoor enclosure from the public side. The night den is to the right.



Plate 2: View of the inside of the capuchin enclosure on the non-public side from where the black and white camera was located.

2.2. Equipment

Two cameras, one (ELMO TPC5504EX Colour) mounted on a five metre high beam above the enclosure pointing downwards (45°) and the other (CBP52 DC B+W Cylinder 3.7 mm cone pinhole) positioned on a tripod 1.3 metres above ground level, four metres from the outside enclosure entrance (Figure 2.1.), were used to observe population and individual behaviour. The B+W camera was positioned 30 centimetres from the enclosure to permit maximum viewing potential, while at the same time just out of reach of the study subjects. The colour camera, positioned on top of a five metre high beam, was two metres clear of the enclosure, thus well out of reach of the study subjects. Each camera was wired to a standard Video Cassette Recorder (VCR) and powered by Mains Grid electricity deriving from a residential property 80-100 metres away. The VCRs were housed in modified plastic containers (55 cm x 40 cm x 15 cm) and wrapped in green tarpaulins. Heavy duty extension cords were used along with surge protected 6-way adapters and connection plug protectors to source the electricity from the residential property. All the equipment used was either standard or modified to suit 240 Volts/50Hz. On a daily basis four 180 minute video cassettes were utilised to record activity with one tape per feeding session per VCR. These tapes required renewal once a month.

2.3. Treatments

The population was presented with four treatments under permit from December 2007 until May 2008 (Appendix 6). These were:

Method 1. Cut food presented in bowls (past method),

- Method 2. Cut food presented randomly around the enclosure (current method at start of study),
 Method 3. Uncut food presented randomly around the enclosure,
 Method 4. Novel feeding devices presented around the enclosure.

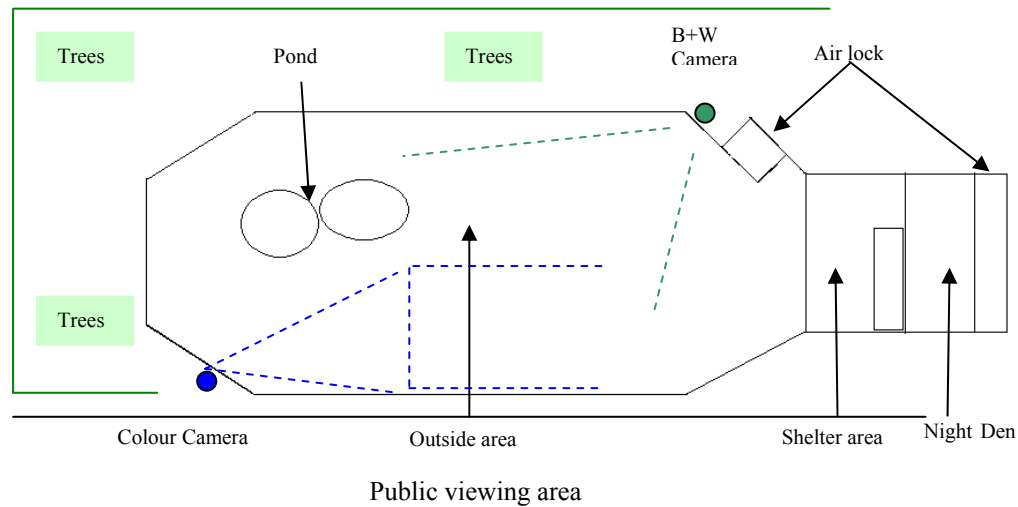


Figure 2.1. Overhead view of enclosure showing positioning of the two cameras (coloured dots) and their relative view (corresponding dashed lines).

The practice of presenting food around the enclosure was the feeding method used prior to commencement of this study. Each method was employed for exactly one month with recording beginning on the first Monday, Wednesday or Friday after an initial 10 day period as research conducted by Hayes (1990) and the findings of Westergaard *et al.* (1998) indicated that ten days is sufficient for this species to become accustomed to a newly appointed feeding method. After the one month expired, the past method of cut food presented in bowls (1) was reemployed for one month. The method was then changed to uncut food presented around the enclosure (3) for one month; this period was then followed by a month of cut food presented in bowls (1) and then a month of the novel feeding devices presented around the enclosure (4). The last treatment was one month of cut food presented in bowls (1) to correlate duration of other employed methods. The duration of this experiment was 183 days and split up using the following approach:

Method 2- December 2007 = 9 days recording = 360 minutes/ day = 3240 min.

Method 1- January 2008 = 9 days recording = 360 minutes/ day = 3240 min.

Method 3- February 2008 = 9 days recording = 360 minutes/ day = 3240 min.

Method 1- March 2008 = 9 days recording = 360 minutes/ day = 3240 min.

Method 4- April 2008 = 9 days recording = 360 minutes/ day = 3240 min.

Method 1- May 2008 = 9 days recording = 360 minutes/ day = 3240 min.

2.4. Treatment methods 1-3

The method of cut food presented in bowls (Method 1) involved presenting cut food in two stainless steel bowls (25 cm diameter x 8 cm depth), one at the front of the enclosure (in relation to public viewing area) in clear view for the B+W camera, while the other bowl was situated close to the rear of the enclosure (in relation to public viewing area) in clear view for the colour camera.

The cut food (Method 2, all dietary items to approximately 2.5 cm³) was spread non-clumped around the enclosure during each feeding session.

The uncut food (Method 3, e.g. whole apples, bananas, potatoes, celery) was spread around the enclosure during each feeding session.

2.5. Novel feeding devices

2.5.1. Drilled macrocarpa logs

The novel feeding devices presented around the enclosure consisted of four separate types. First, three identical logs (Plate 3) were made from two 1.8 m x 0.3 m x 0.1 m macrocarpa sleepers. The logs each consisted of two 0.6 m long sections of hardwood sleeper, bolted together with two 21 cm bolts. Six 1.2 cm and four 0.8 cm diameter holes were drilled on one side of each log to a depth of 6.5 cm (later drilled to 10 cm due to failure to insert food into the holes because of pressure build up). Two 0.45 m x .32 cm chains were attached to the sides of each log with 1.0 cm saddle pipe clamps. The end of each chain was padlocked together around the wooden beams at the back of the enclosure. Only two of the three drilled logs were used at any one time, due to cleaning purposes.



Plate 3. Drilled macrocarpa logs.

2.5.2. Defined foraging area

Second, a defined foraging area (Plate 4) was designed out of 10 x 10 cm timber. The sides of the foraging area were 2.7 m in length and were attached to a centre hinged 3.2 m backing by 25 cm hinges, allowing an area of 8.64 m². Once constructed the timber could be folded in and out in a concertina-type fashion. This apparatus was designed for and placed around two parallel wooden beams at the front of the enclosure. Half a bale of wheat straw was spread in this area to an average depth of 6.0 cm.



Plate 4. Defined foraging area with straw bed

2.5.3. Foraging boxes

Third, two foraging boxes (19.4 cm (length) x 19.4 cm (width) x 55 cm (height)) were constructed from 1.2 cm plywood with a PVC pipe interior (Plate 5). The plywood was screwed onto 2.4 cm x 2.4 cm x 52.6 cm pinewood. The top of the box was attached using 10 cm hinges and locked in place using a 10 cm latch and padlock. The pipe (15 cm in diameter and 49.5 cm long (with end cap) was fitted with two stoppers (2.4 cm x 10 cm), one bolted on each side to stop the pipe from rotating within the box. Five circular holes (2.2 cm; 2.8 cm; 3.2 cm; 3.8 cm and 4.4 cm in diameter), at 5 cm spacings, were drilled in the same position in the wood and the pipe. Also, a rectangular hole (7.5 cm x 2.5 cm) was made in the upper section of the box and pipe and a rubber flap (10 cm x 8.75 cm x 0.4 cm) was attached to hide its exterior. High tensile rope (1.2 cm diameter x 28 cm) was knotted onto the top of each pipe to facilitate removal. These apparatus were attached to the beams at the front of the enclosure, above the foraging area. They were connected to the beams using four 0.28 m x 0.32 cm chains and two 0.5 cm hook and eye turnbuckles. The chains were attached to the box using four 1.0 cm saddle pipe clamps.



Plate 5. Foraging boxes displaying interior pipe

2.5.4. Modified Kong[®]'s

Fourth, five Kong[®]'s (Extreme King; dog toys) were modified using rope (1.2 cm diameter x 45 cm; Plate 6). The rope was passed through each Kong[®], tethered at each end and knotted at appropriate distances to block the larger opening. This apparatus was not in a fixed position and was free to be moved within the enclosure. Only two of the five Kong[®] per feeding session were used, mainly due to cleaning purposes and food preparation.



Plate 6. Modified Kong[®]'s

2.5.5. Chambered pipe (non-enrichment)

Another PVC pipe (9.0 cm diameter x 60 cm (with screw cap; Plate 7) was used to transport desirable foods to the allocated apparatus. Two rectangular holes (7.5 cm x 1.2 cm) were made 25 cm and 50 cm from the screw cap to fit two plywood (1.2 cm) stoppers that were shaped to fit the inside curve of the pipe. This divided the pipe into two chambers, which was each allocated the food for each foraging box. Two chains (0.32 cm x 18 cm) were bolted onto the stoppers and the pipe to stop them from being lost.



Plate 7. Chambered pipe used for transporting desirable foods.

2.6. Novel feeding device use

The devices used were modified from Hayes (1990) – boxes; Anderson and Chamove (1984) – straw foraging area and Lavallee (1999) – drilled logs. The Kong®s were suggested by the head zoo keeper (pers. comm. Monique van der Linden Hagedoorn, 16th January, 2008) at Willowbank and the chambered pipe was designed by the author to solve the problem of food security and transport within the capuchin enclosure.

Due to some foods being more desirable than others, some of the apparatus showed little to no use in the first few days of introduction. Therefore, a decision was made to allocate the most desirable foods to the apparatus that were used the least.

The drilled logs were allocated half of one banana and half of one hard boiled egg, per feeding session. These were pressed into the drilled holes.

Within the foraging area, five and a half apples, seven slices of bread/pellets, two carrots, 100 g cheese, 150 g cooked rice, one bunch spinach/celery, four kiwifruit and three cooked potatoes were evenly spread throughout the straw per feeding session. The half bale of straw was replaced once a week (Friday) during the time the enclosure was cleaned.

The foraging boxes were allocated 7.5 bananas, 3.5 hard boiled eggs and 35 grapes, which were then split into two boxes. A large handful of straw was first placed in the boxes then the food was dropped in using the divided pipe and another handful of straw placed on the top to sandwich the food.

Two Kong®s per session were each packed with 1/8 cup of sultanas and ¼ apple cut into 1.0 cm² pieces. The rope was then pulled to compact and block the large opening.

2.7. Recording activity

Preliminary observations began in November 2007. These observations were used to determine the type of cameras to employ, camera positions and distances.

Indirect observation (camera recording) was active prior to (30 min.), during and after, each of the two daily feeding sessions, three days each week over the entire study. A focal animal technique was not used due to the inability to reliably identify individuals on video.

A period of intense foraging was observed directly after feeding where virtually no other behaviour was apparent. The duration of the intense foraging was also recorded but no detailed records of behaviour were taken during this period. The period of intense foraging was determined using the following rules: equal to or above three (≥ 3) individuals foraging at any one time equals intense foraging; equal to or below two (≤ 2) individuals foraging above two (> 2) minutes equals the end of intense foraging. After the intense foraging ceased another 30 minutes of video recording began.

The camera footage was examined on a monitor the day following each recording. Continuous records were taken from the videos for each individual's behaviour on a purposefully designed printed spreadsheet (Appendix 7). Behaviours were identified (Plate 8) and arranged (modifying Hayes's 1990 approach) into the following categories:

1. Foraging (eating or attempting to procure food)
2. Locomotion (walking, running, climbing, jumping)
3. Resting (inactive, looking around)
4. Other (self grooming or social grooming, manipulating exhibit, social behaviours, playing, stress-related behaviours)



Plate 8. Top left: Preg and unknown female illustrating foraging behaviour. Top centre: Ben illustrating typical locomotory behaviour. Top right: Paris and unknown female illustrating grooming behaviour. Bottom left: Johnny illustrating resting behaviour. Bottom right: Ben and Johnny illustrating other behaviour (i.e. play fighting). Note: individual monkey identification on film was not reliable; these pictures are from a still-photo camera.

In addition to recording the behaviour of *Cebus apella* during this study, other variables were recorded, such as daily temperature (Burwood, Christchurch, New Zealand Lat.-43:29:25 Long.-172:41:08 Elevation (Ground): 34 metres. above sea level), precipitation (Burwood, Christchurch, New Zealand Lat.-43:29:25 Long.-172:41:08 Elevation (Ground): 34 metres. above sea level) and daily visitor numbers (Willowbank administration records).

The records of the behaviours, temperatures, precipitation, and visitor numbers were later transferred to a Microsoft Excel spreadsheet and then summarised. The behaviours were summarised into the different categories (listed above) and a sum of the count and duration of each behavioural category was determined.

2.8. Data analysis

2.8.1. Period of intense foraging data

To score the intense foraging period, the duration of intense foraging (mins.) was calculated per feeding session over the different feeding treatments for the observed subjects. Analysis of the data using a General Linear Model (GLM) with normal error distribution was then used to compare between the different feeding treatments. Where significant effects were identified, post-hoc multiple comparisons were conducted using Fisher's LSD test (5%). All analyses were conducted using GenStat Version 10.

Only the last four feeding treatments were analysed because the data for the first two feeding treatments differed, to that of the other feeding treatments, because estimation, rather than a true measure of the period of intense foraging was taken.

2.8.2. Behaviour data

For the behaviours to be scored we calculated the frequency (i.e. count) and the time (secs.) over the different feeding treatments for the observed subjects (pre- and post- the period of intense foraging).

To standardise the data both the count and duration data were converted into a proportion of all behaviour observed during the video period. Accordingly, the dependent variable was the proportion of time or number of times a single behaviour occurred out of all the behaviours observed in one observation period. The reason this approach was adopted was that it became apparent that all activity reduced as the study moved into winter (see Appendix 8). If this had not been undertaken then any feeding treatments presented in winter would have been under-reported as all behaviour was decreased with declining temperatures. This would not have been an issue if application of the different feeding treatments at random throughout the feeding trial had been possible. Unfortunately, this was not logistically possible and the animals were always put back on feeding Method 1 between each different feeding treatment in an attempt to 'reset' behaviour before a new feeding method was presented.

Restricted maximum likelihood (mixed model REML) estimation was then used to assess the effect of the different feeding treatments on the duration of scored behaviour in the study population.

Also included within the statistical modelling was, time of feeding, time of day and keeper- to assess whether these influenced on the frequency and duration of scored behaviours, for each feeding treatment.

2.8.3. Foraging device data

Foraging devices were scored by identifying and recording each foraging event and the duration over the different feeding devices, for the observed subjects, during the enrichment feeding treatment.

Comparison between the foraging devices was determined by the proportion of counts and time spent utilising each foraging device out of a total count and duration spent utilising all devices for each feeding session. This was then also analysed using a mixed model REML to determine which feed device was most utilised. This data was log transformed (right skewed) to ensure normality. Again, all post-hoc multiple comparisons were conducted using Fisher's Protected LSD test (5%).

3. Results

The feeding treatments have been abbreviated and are as follows:

C.I.B. – cut food in bowls (numbered 1 – 3)

C.A.E. – cut food presented randomly around enclosure

U.A.E. – uncut food presented randomly around enclosure

ENRICH – four forage enrichment devices presented around the enclosure

3.1. Period of intense foraging

Analysis of the last four feeding treatments indicated that the period of intense foraging was significantly influenced by the feeding treatment ($F_{3,60}=120.22$; $P<0.001$). Pairwise comparisons of the different feeding treatments indicated that the period of intense foraging for the enrichment treatment was significantly longer than all other treatments (Figure 3.1). Also, the enrichment treatment was significantly higher when compared to all the other feeding treatments combined (1 df orthogonal contrast; $F_{1,60}= 332.02$; $P<0.001$). There was no significant effect for any other factors. The longest period of intense foraging was during the enrichment treatment and was recorded as the 140 minute maximum (see Methods). Only one occurrence of intense foraging below 60 minutes was recorded during the enrichment treatment and only one incident of intense foraging above 60 minutes was recorded outside of the enrichment treatment and occurred during the C.I.B.3 treatment.

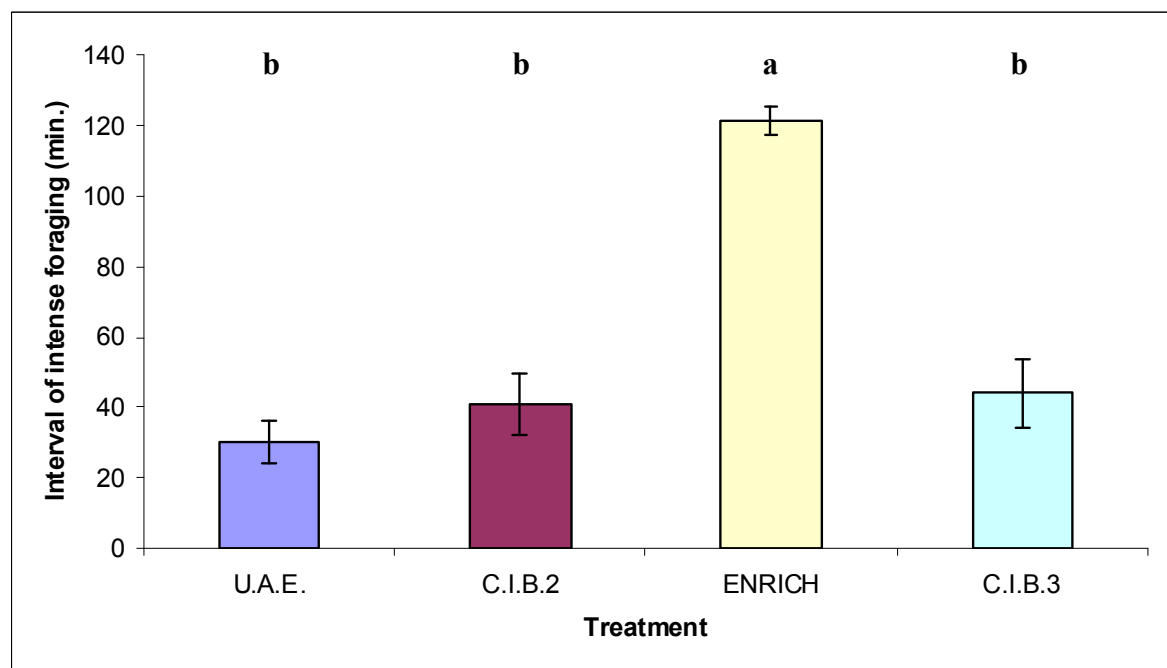


Figure 3.1. Mean period of intense foraging (minute's \pm SEM) by capuchins showing the enrichment feeding treatment significantly higher than all other feeding treatments. Letters indicate significant differences (Fishers LSD 5%).

Foraging behaviour

3.2. Numbers of observed foraging events (count data)

Over all treatments, an average of 17.6% of the capuchins behaviour was counted as a foraging event. When foraging was divided into pre- and post-feed times significantly more (22%; $F_{1,88}=153.81$; $P<0.001$; Figure 3.2a.) foraging occurred in the post-feed time period.

Pairwise comparisons of the different feeding treatments indicating that enrichment was significantly higher than the other feeding treatments ($F_{5,88}=12.47$; $P<0.001$; Figure 3.2b.). Again, enrichment showed a significantly greater proportion of foraging events when compared to all other feeding treatments combined (1 df orthogonal contrast; $F_{1,88}=42.37$; $P<0.001$).

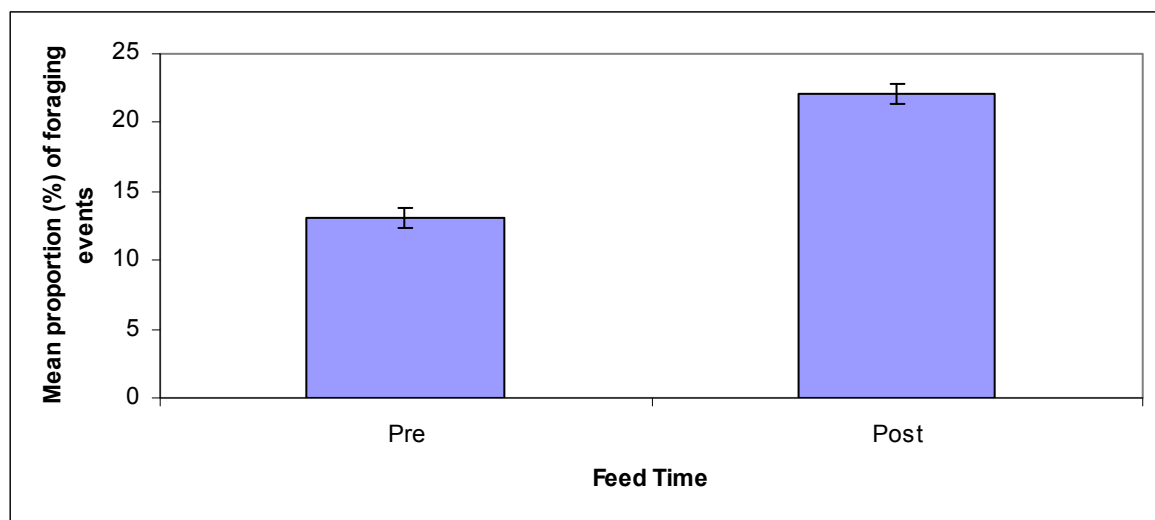


Figure 3.2a. Mean proportion of pre- and post- foraging events (\pm SEM) showing that post feed time foraging events were significantly higher than pre feed time foraging events.

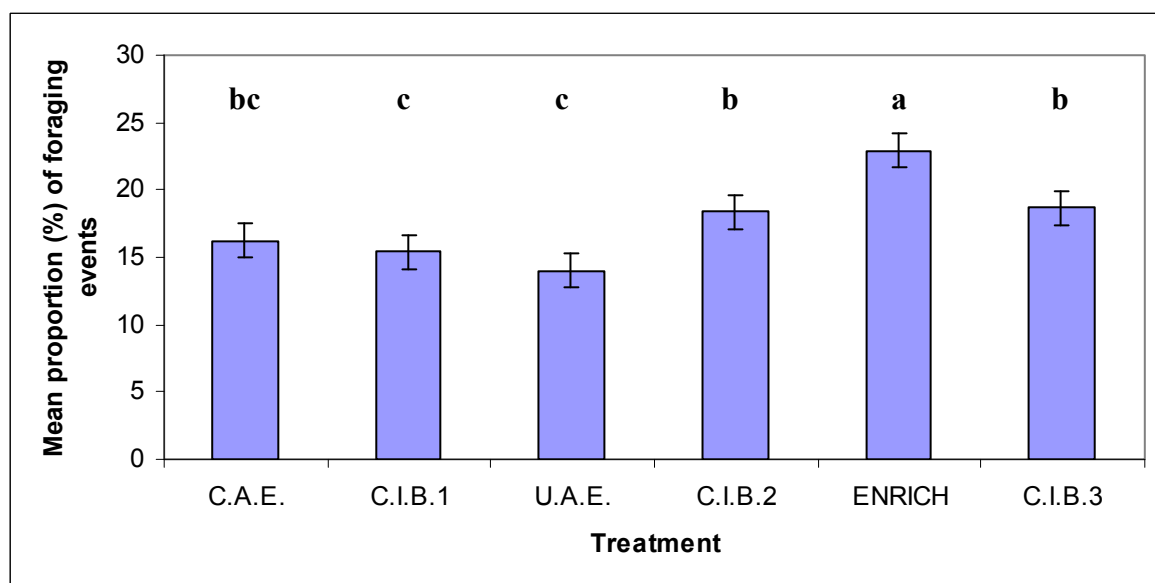


Figure 3.2b. Mean proportion of foraging events (\pm SEM) showing that the enrichment feeding treatment was significantly higher than all other feeding treatments. Corresponding letters indicate no significant difference (Fishers LSD 5%).

3.3. Proportion of total time spent foraging (time data)

Over all, the capuchins spent an average of 39% of their total time foraging. Again, when this was split into pre- and post-feed times foraging, the results indicated significantly longer post-feed foraging ($F_{1,88}=124.62$; $P<0.001$; Figure 3.3a.).

Pairwise comparisons of the different feeding treatments showed that enrichment had a significantly greater proportion of time spent foraging than the other feeding treatments ($F_{5,88}=6.51$; $P<0.001$; Figure 3.3b). Again, enrichment showed significantly longer time spent foraging when compared to all other feeding treatments combined (1 df orthogonal contrast; $F_{1,88}=19.66$; $P<0.001$).

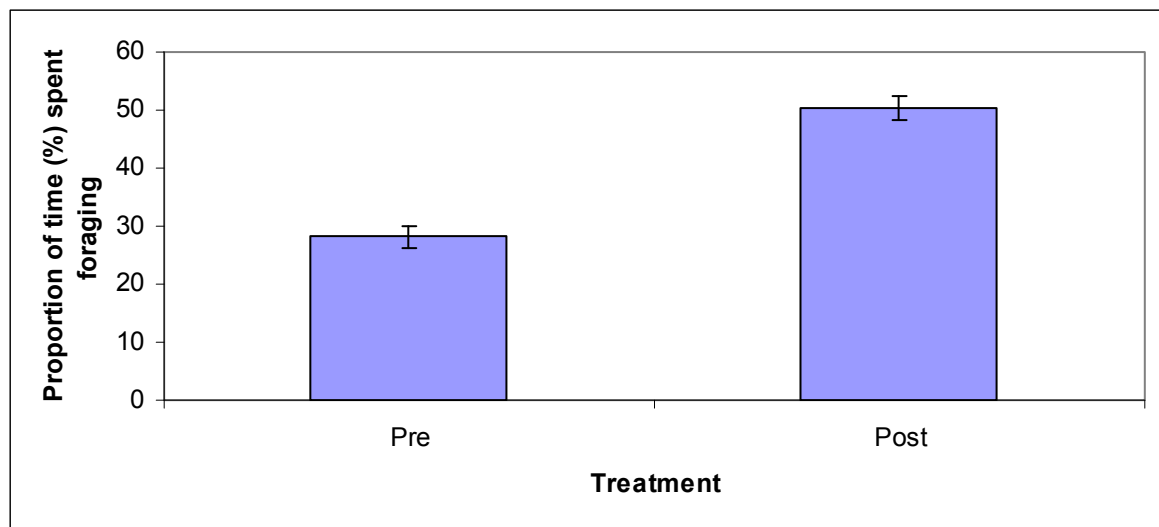


Figure 3.3a. Mean proportion of time spent foraging in pre- and post-feed time (\pm SEM) showing significantly longer post-feed time foraging.

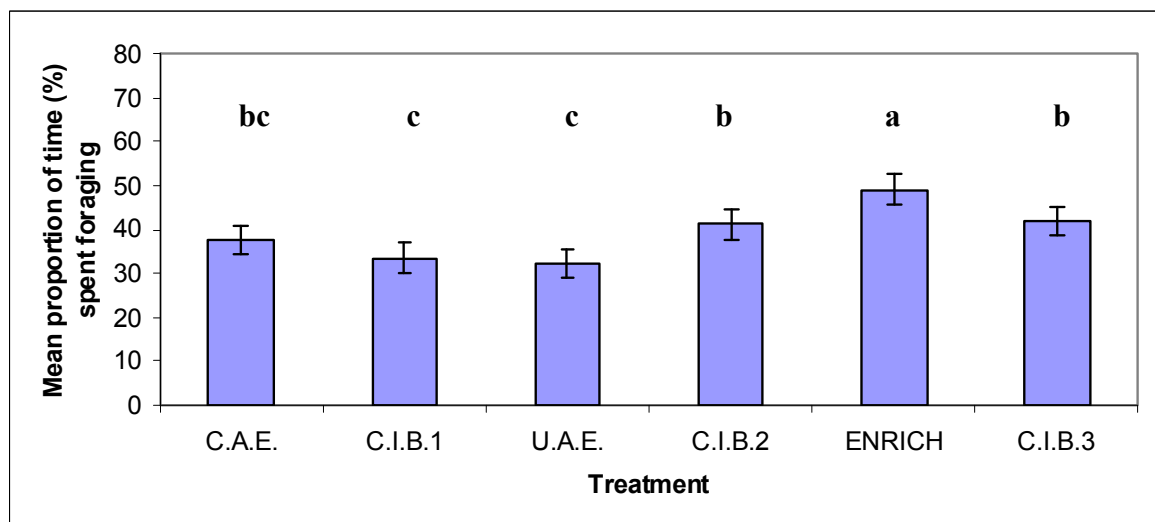


Figure 3.3b. Mean proportion of time spent foraging (\pm SEM) showing significantly longer time in the enrichment feeding treatment. Corresponding letters indicate no significant difference (Fishers LSD 5%).

Locomotion behaviour

3.4. Numbers of observed locomotion events (count data)

A mean of 55.3% of the capuchins behaviour was counted as locomotion. When locomotion was divided into pre- and post-feed times there was no significant difference ($F=0.03$; $P=0.863$).

Pairwise comparisons of the different feeding treatments indicating that enrichment treatment was significantly lower than most (with exception of U.A.E.) other feeding treatments ($F_{5,88}=5.49$; $P<0.001$; Figure 3.4). However, the enrichment feeding treatment showed a significantly lower proportion of locomotion events when compared to all other feeding treatments combined (1 df orthogonal contrast; $F_{1,88}=15.31$; $P<0.01$).

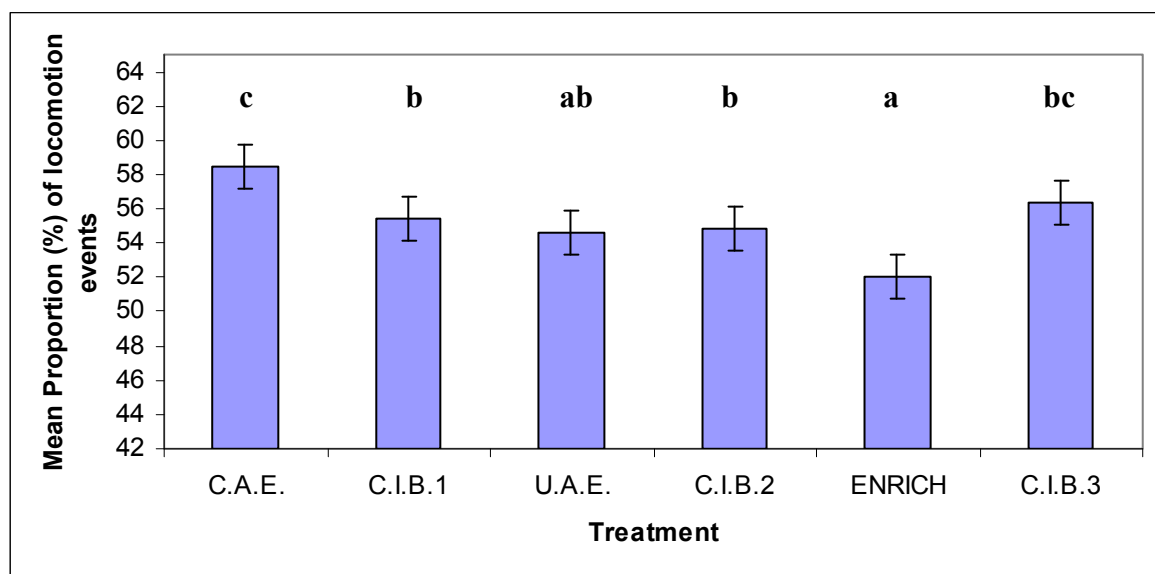


Figure 3.4. Mean proportion of locomotion events (\pm SEM) showing a significant effect over varying experimental treatments. Corresponding letters indicate no significant difference (Fishers LSD 5%).

3.5. Proportion of total time spent on locomotion (time data)

Capuchins spent 20% of the total time on locomotion. Again, when this was split into pre- and post-feed times, the results indicated no significant difference ($F=2.65$; $P=0.107$).

Pairwise comparisons of the feeding treatments showed that there was a significant treatment effect ($F_{5,88}=6.98$; $P<0.001$; Figure 3.5). The C.A.E. feeding treatment showed significantly higher proportion of time spent on locomotion when compared to most other feeding treatments.

Again the enrichment treatment showed a significantly lower proportion of time spent on locomotion when compared to all other feeding treatments combined (1 df orthogonal contrast; $F_{1,88}=12.62$; $P<0.001$).

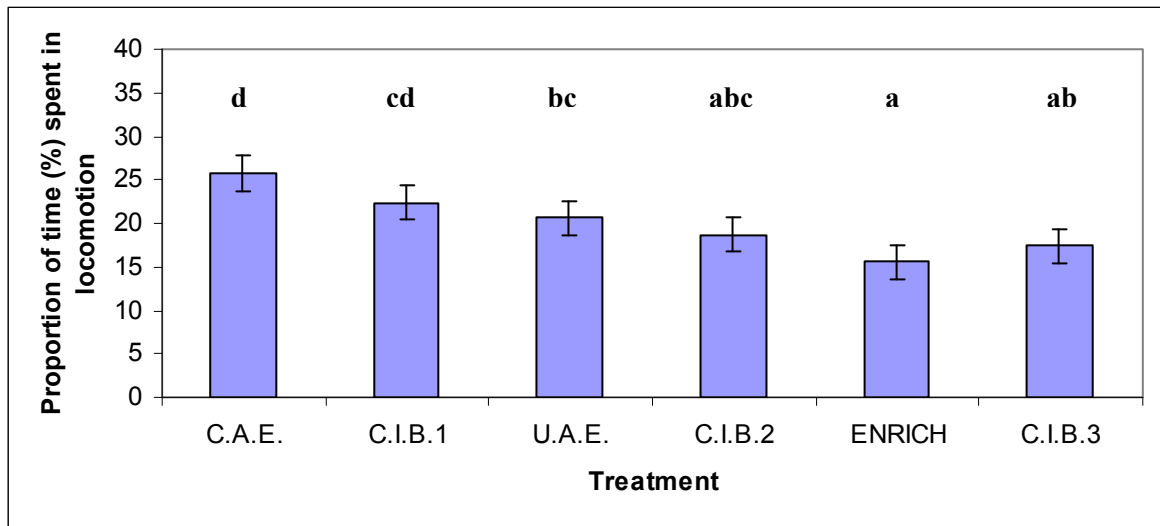


Figure 3.5. Mean proportion of time spent on locomotion (\pm SEM) showing significant effects between varying experimental treatments. Corresponding letters indicate no significant difference (Fishers LSD 5%).

Resting behaviour

3.6. Numbers of observed resting events (count data)

A mean of 55.3% of the capuchins total behaviour was counted as resting events. When resting was divided into pre- and post-feed times there was significantly more rest occurred in the pre-feed time (25.6%; $F_{1,88}=66.82$; $P<0.001$) and there was a significant difference between the feeding treatments ($F_{5,88}=14.85$; $P<0.001$) with enrichment lower than most other feeding treatments. However there was also a significant treatment by feed-time interaction ($F_{5,88}=3.57$; $P=0.005$; Figure 3.6). The number of observed resting events within feeding treatments was influenced by feed time, however, the enrichment feeding treatment showed no significant influence of feed time.

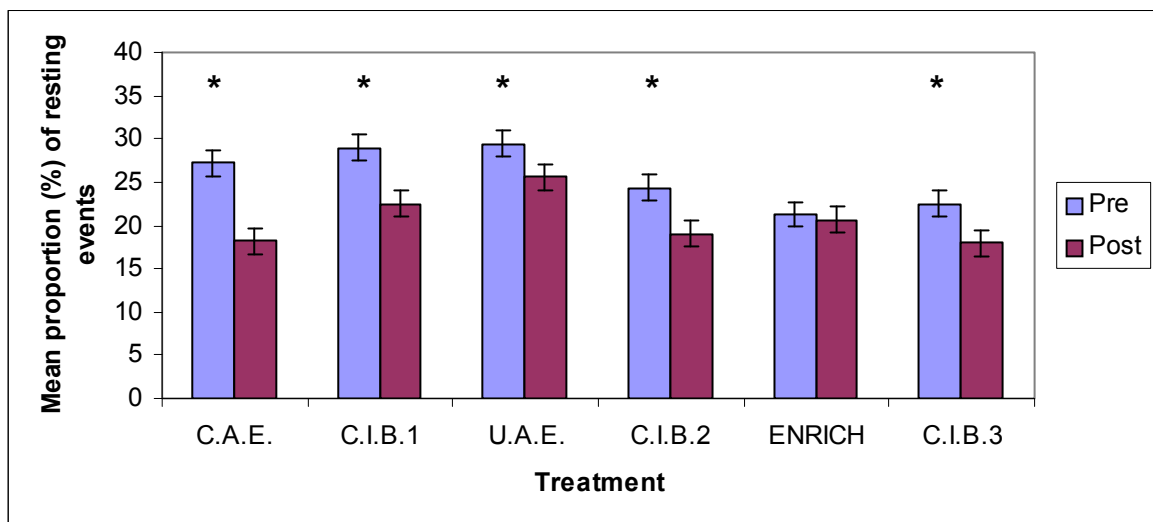


Figure 3.6. Mean proportion of resting events (\pm SEM) showing significant effects in pre- and post-feed times over varying experimental treatments. Stars indicate significance between pre- and post-feed times within feeding treatments (Fishers LSD 5%).

3.7. Proportion of total time spent resting (time data)

The capuchins spent 28% of their total time resting. Again, when this was split into pre- and post-feed time resting, the results indicated a significantly higher pre-feed resting ($F_{1,88}=51.41$; $P<0.001$) and there was a significant treatment effect ($F_{5,88}=5.29$; $P<0.001$). The U.A.E. feeding treatment was significantly higher than all but C.I.B.1. Again, there was a significant treatment by feed-time interaction ($F_{5,88}=3.03$; $P=0.014$; Figure 3.7) with the proportion of time spent resting within feeding treatments influenced by feed time, except for the enrichment feeding treatment.

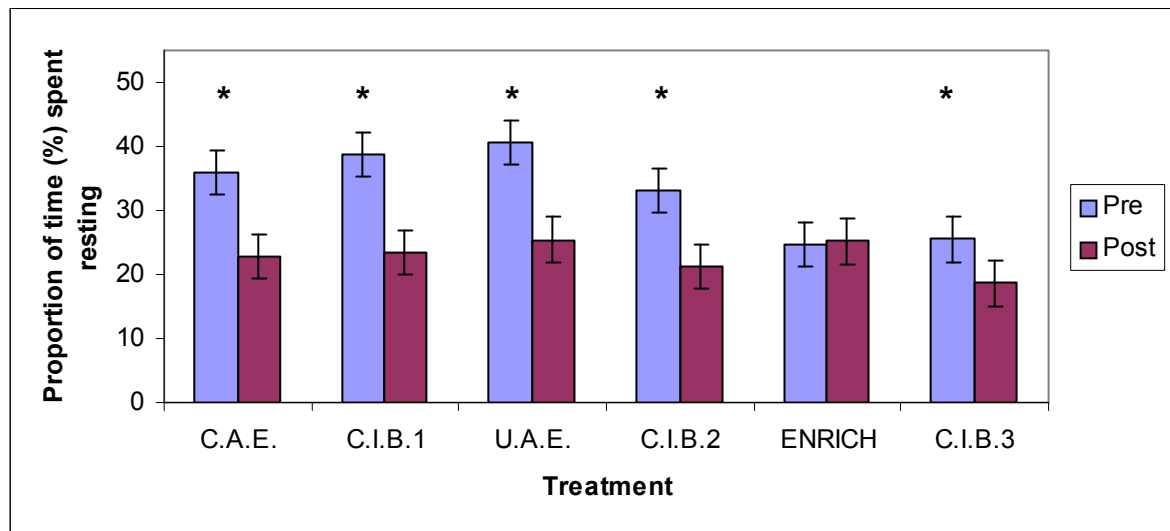


Figure 3.7. Mean proportion of time spent resting (\pm SEM) during pre- and post-feed times showing a significant effect over varying experimental treatments. Stars indicate significance between pre- and post-feed times within feeding treatments (Fishers LSD 5%).

Other behaviour

3.8. Numbers of observed other behaviour combined events (count data)

Other behaviour included grooming, social-grooming and other minor behaviours, which were combined in our analyses due to their very low occurrence.

Over all treatments, an average of 4% of the capuchins behaviour was counted as other behaviour events. When other behaviour was split into pre- and post-feed times significantly more other behaviour occurred in the pre-feed time period (5.9%; $F_{1,88}=82.77$; $P<0.001$) and there was a significant difference between the feeding treatments ($F_{5,88}=2.78$; $P=0.022$). Again, there was a significant treatment by feed-time interaction ($F_{5,88}=3.05$; $P=0.014$; Figure 3.8) with the difference in the pre- and post-feed time dependent upon the feeding treatment.

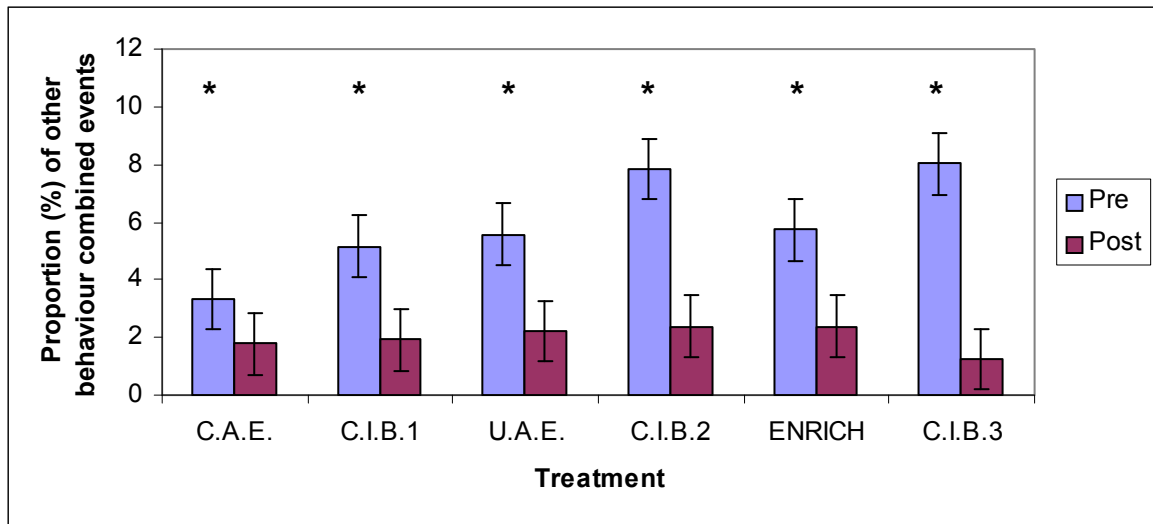


Figure 3.8. Mean proportion of other behaviour combined events (\pm SEM) in pre- and post-feed times showing significant effects over varying experimental treatments. Stars indicate significance between pre- and post-feed times within feeding treatments (Fishers LSD 5%).

3.9. Proportion of total time spent on other behaviour combined (time data)

The capuchins spent 13% of their total time on other behaviour. Again, when this was divided into pre- and post-feed time other behaviour, the results indicated a significantly longer pre-feed time other behaviour ($F_{1,88}=44.56$; $P<0.001$) and there was no significant difference between the feeding treatments ($F_{5,88}=2.23$; $P>0.05$), although, there was a significant treatment by feed-time interaction ($F_{5,88}=2.48$; $P=0.038$; Figure 3.9). The proportion of time spent on other behaviour within feeding treatments was influenced by feed time. Figure 3.9 shows that the proportion of time spent on other behaviour was much longer in pre-feed time over all feeding treatments.

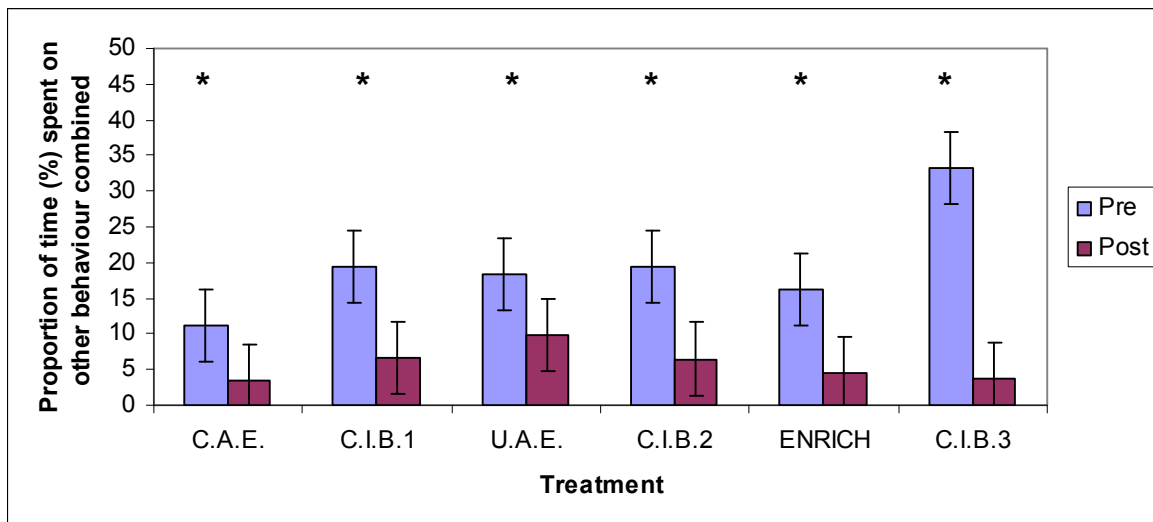


Figure 3.9. Mean proportion of time spent on other behaviour (\pm SEM) during pre- and post-feed times showing significant effects over varying experimental treatments. Stars indicate significance between pre- and post-feed times within feeding treatments (Fishers LSD 5%).

3.10. Abnormal behaviours

Abnormal behaviours were counted within the “other” behaviour category. When abnormal behaviours were observed independently from the other behaviours the results indicated a variety of abnormal behaviours occurring within the first three treatments (i.e. C.A.E., C.I.B.1 and U.A.E.; Table 3.10). They were observed approximately once a day. However, during the last three months of this study there was no abnormal behaviour observed. Abnormal behaviour in the form of guarding of food and low aggression were not observed during this study.

Table 3.10. List of abnormal behaviours, their frequency and the treatment/month of occurrence observed during this study.

Treatment/ month	Description	Frequency of occurrence
C.A.E./December	Spinning in circles	13
	Back-flipping off cage	1
C.I.B.1/January	Spinning in circles	1
	Licking metal enclosure cage	1
U.A.E./February	Spinning in circles	3
	Playing with food/no consumption	1
	Back flip through rope loop	1
	Pacing	3
	Alpha male submissive and mounted	2
C.I.B.2/March	None observed	0
ENRICH/April	None observed	0
C.I.B.3/May	None observed	0

Analysis of the different foraging devices

3.11. Numbers of observed foraging device use events (count data)

During the enrichment treatment, a mean of 63% of the capuchins’ foraging was counted as utilising an enrichment device (i.e. single periods of manual manipulation). When foraging was split up into the different devices, there was a significant difference in the frequency of use ($F_{3,174}=29.31$; $P<0.001$; Figure 3.11) with the box device used significantly more than the other devices.

There was no significant effect (mixed model REML; $P>0.05$) of day, feed (pre/post) or time of day (am/pm) on the utilisation of the foraging devices.

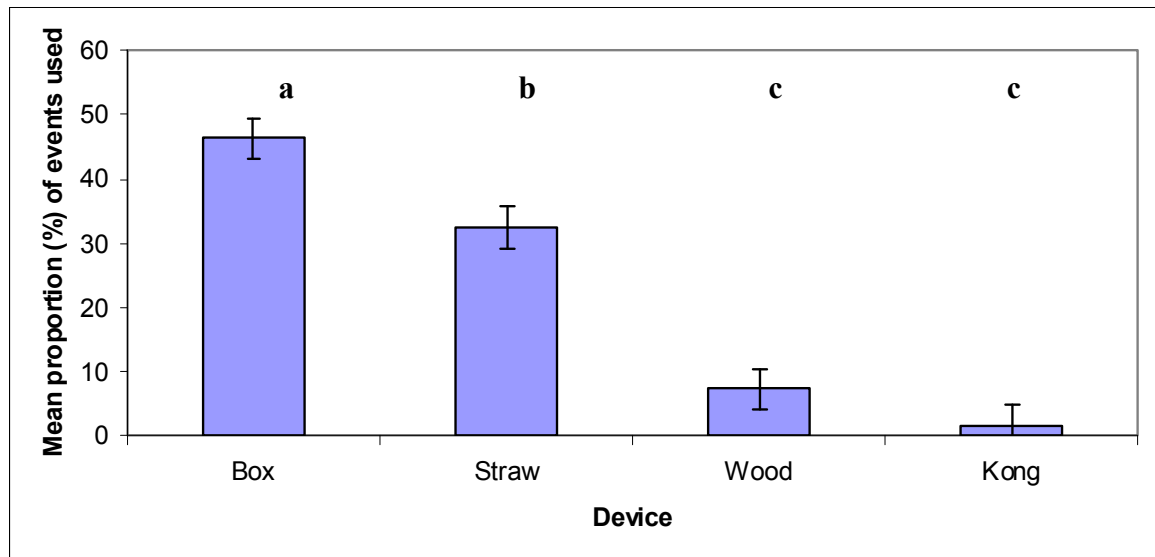


Figure 3.11. Mean proportion of events for each device (\pm SEM) showing the box was significantly higher than the other devices. Corresponding letters indicate no significant difference (Fishers LSD 5%)

3.12. Proportion of total time foraging devices were use (time data)

A mean of 62 % of the total time the capuchins foraged utilising the enrichment devices. When foraging was split into use of the different devices, there was a significant difference in the proportion of time each device was utilised ($F_{3,170}=18.49$; $P<0.001$; Figure 3.12) with the box and straw used significantly longer than the other devices.

There was no significant effect ($P>0.05$) of day, feed (pre/post) or time of day (am/pm) on the proportion of time spent using the foraging devices.

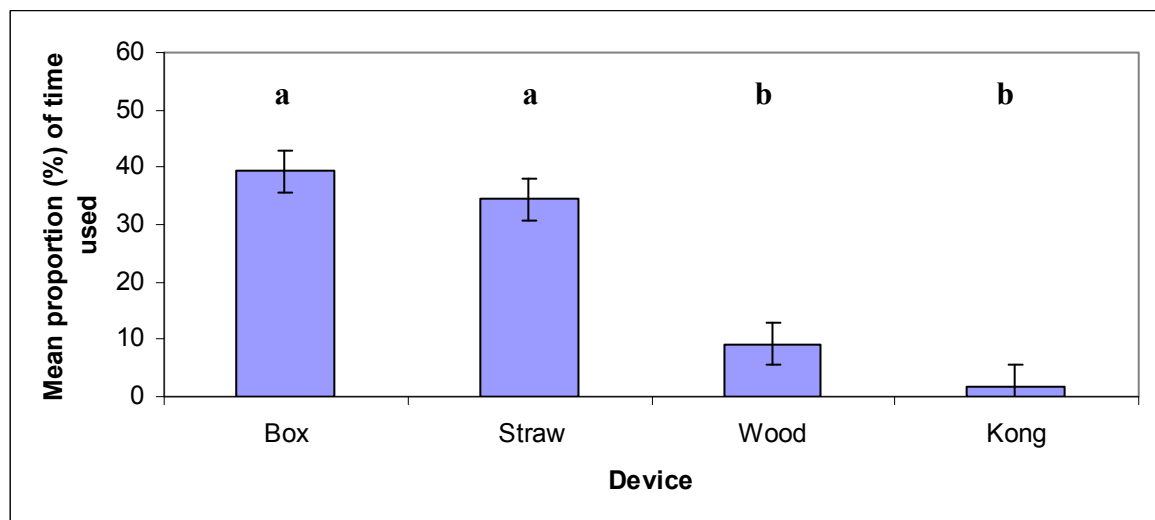


Figure 3.12. Mean proportion of time each device was used (\pm SEM) showing that the box and straw was used significantly longer than the other devices. Corresponding letters indicate no significant difference (Fishers LSD 5%).

Discussion

Study Design

During this study there was no opportunity to split the population into replicates of the original capuchin population due to logistical issues with housing and the potential instability in dominance rankings between some individuals once reintroduced. In place of a control, the three feeding treatments were interleaving with cut food in bowls (C.I.B.).

The C.I.B. treatments were designed as a baseline for behaviour of the capuchins before any new feeding treatment commenced. Six months prior to the start date of this study, the C.I.B. method of feeding was the original form of dietary presentation. Therefore, C.I.B. was used as a baseline treatment between the three other feeding treatments so that the three feeding treatments could be analysed separately and reduce any cross-over effects from the previous feeding treatment.

The intense foraging rule (see Methods), i.e. ≥ 3 individuals foraging at any one time equals intense foraging; ≤ 2 individuals foraging > 2 minutes equals the end of intense foraging, was a useful tool in an attempt to record variations between the lengths of time over the feeding treatments. The accuracy and precision of this rule was completely dependant upon the perception of the observer and therefore could be biased if there was more than one observer. However, in this study there was only one observer; therefore, the data may only be biased one way.

As the brief explanation in the Methods revealed, the temperature, precipitation and visitor numbers that were analysed in this study suggested that each variable was correlated with the other two variables and that when analysed against behaviour, reduced all activity as time progressed. Therefore as temperature and visitor numbers decreased, activity responded accordingly. Precipitation was correlated with temperature and visitor numbers and showed an increase over time which correlated to a decrease in activity (Appendix 8). If these variables were to be incorporated into the analysis then the winter feeding treatments would have been under-reported due to the non-random feeding methods employed.

Direct observation to complement the cameras would have been beneficial and provided additional information such as gender related activities and perhaps individual related activities. Unfortunately, direct observation was not possible due to the behavioural change in the capuchins when the observer was present. The capuchins associated the observer with food and grouped together as close to the cage were the observer was present, out of camera view and remained in this location until the presence of the observer was removed.

Enrichment devices without the incorporated food presented in the enclosure to assess whether the foraging devices themselves are associated with activity changes could have been accomplished, however feeding of the capuchins via a different method may have influenced their behaviour and may not have been representative of the populations activity with the enrichment devices without food. Also, presenting the devices to the capuchins without food, removes the novelty of the devices prior to their use with food and the use of the enrichment devices after the devices with food stage would have over-reported their activity as they associate the devices with food.

Discussion of results

The data suggested that the enrichment treatment was associated with a variety of positive behavioural modifications in the capuchin population, compared to baseline months when food was presented in bowls. During the enrichment treatment the monkeys not only spent a longer time intensely foraging, they also engaged in more foraging behaviour and less locomotion and resting behaviour. Data from wild populations indicates that capuchins spend from 65% to 93% of their time in foraging and on locomotion behaviours (Baldwin & Baldwin, 1977; Hayes, 1990; Izawa, 1980) and as little as 4% spent on resting (Izawa, 1980). The behavioural modifications associated with enrichment suggest an alteration in the time budgets and frequency of occurrence towards a more typical wild capuchin population. Whether the behaviour of the wild animal is a good model for improving animal welfare is debateable (see Veasey *et al.*, 1996) on the grounds that non-performance by captive animals of some of the behaviours shown by wild-living animals does not necessarily indicate reduced welfare (Hosey, 2004). In a captive environment it seems clear that audience presence, restricted space and being managed are three factors that affect primate behaviour (Hosey, 2004). However, it would be a mistake to assume that wild environments are characterised by a lack of these features. With the available space of non-captive primates continually declining through human impact, many species have to change their ecology and behaviour in order to survive (Hosey, 2004). Many non-captive primates regularly encounter humans through tourism, raiding of human crops and garbage or because of the bush-meat trade. So, in some of these variables zoo and some wild environments are increasingly similar (Hosey, 2004). These perspectives recognize that wild-living animals face stressors too, and can experience compromised welfare (Hosey, 2004).

A common assumption is that primates show great adaptability and flexibility and that zoo environments should be within their range of adaptability (Poole, 1991), although it is generally assumed that the zoo environment is a more extreme one than the other environments in which primates live (with the likely exception of laboratories) (Hosey, 2004).

Providing foraging opportunities has been shown to be a valuable component of environmental enrichment (Baker, 1997) and may substantially promote species-typical behaviour and improve the well-being of captive primates (Lutz & Novak, 2005). However, zoos should not push the foraging time of their captive animals beyond those reported for their wild counterparts if they wish to achieve comparable reproductive success (Young 1997). If, as happens with a highly-endangered species, the objective of a zoo is to increase reproductive output beyond that of wild counterparts, then foraging time less than that of wild counterparts may be beneficial towards this aim (Young 1997).

It is noteworthy that the foraging boxes and the straw foraging area were the two devices that showed increased attractiveness to the monkeys during the enrichment period. The positive correlation between the box/straw devices and the rate of utilisation suggests that these two devices displayed complex food acquisition through increased manipulation and touch dependency. However, it is plausible that the increased use of these devices, over the wooden logs and Kong[®]'s, simply reflects the quantity of food available. This could be addressed in future by allocating the same quantity of food to all devices or by introducing more wooden logs and Kong[®]'s and/or reducing the boxes and straw foraging area.

The period of intense foraging also increased during the enrichment treatment indicating a greater complexity in food acquisition. These findings do not appear to be separate from

foraging rate or total time spent foraging as in other studies, although they may be important from a management perspective. The period of intense foraging, where no other behaviour was observed, is an important measure as at a certain time following intense foraging other behaviours become apparent, including undesirable behaviours. If, increasing beneficial activity through stimulation is effective, then we can eliminate or reduce unwanted behaviours by eliciting and enhancing normal activities, such as the period of intense foraging. This is supported by the present study where pre-feed time resting was significantly greater than post feed-time resting during all treatments except the enrichment treatment where pre- and post-feed time resting were balanced.

Other effects of the enrichment treatment provide evidence for the use of these foraging devices as promoting desirable behaviours in these monkeys. First, it was the only treatment that allowed for non-visual food acquisition, thereby resembling the wild behaviour observed by Izawa (1979) of capuchins putting their hands into the slits of the internodes of *Bambusa guadua* and depending on touch to remove, most commonly, grasshoppers. Second, it promoted increased manipulation incorporating visual inspection thereby resembling the behaviour of sifting through leaf litter observed in wild capuchin monkeys (Defler, 1979). Third, it promoted the incorporation of tools in the acquiring and processing of food which has been observed frequently in wild populations (e.g. Boinski *et al.*, 2000; Izawa & Mizuna, 1977; Struhsaker & Leland, 1977).

The U.A.E. treatment also promoted tool use where hammers, anvils and hitting food against a hard substrate were observed. This method of tool use was more prominent in the U.A.E. treatment almost certainly because of the food presentation, i.e. uncut or whole foods. Tool use during the enrichment treatment was exclusively employed for removing food from the devices. During one particular event a monkey failed to remove food from the wooden logs, left the area for a few seconds, only to return with a cabbage tree (*Cordyline australis*) leaf, which he whittled down to an appropriate width using his teeth whilst holding the leaf in his hands and then proceeded to attempt to remove food from the logs. Therefore, another advantage of the enrichment technique is the promotion of advanced cognitive thought, produced by the monkeys having to perceive ways to remove food from the devices, producing or modifying tools that are appropriate and having the ability to repeat the procedure in the future.

In general any beneficial behavioural changes observed during the C.A.E. and U.A.E. treatments only occurred in post-feed time resting and other behaviours. This suggests that there was a small influence of these treatments on the behaviour of the capuchins and that the influences that were observed did not last through to the next feeding session. In some instances, randomly presenting cut or uncut food around the enclosure appeared to be as effective as presenting cut food in bowls, suggesting that these techniques may not be adequate as an environmental enrichment for this population. However, other benefits associated with random presentation of food must be acknowledged and include insurance of food access to all individuals, selection of a balanced diet by dominant individuals and lowered aggression resulting from a food source that can not be defended (Young, 1997). Contrastingly, the individuals of this study displayed a balanced diet, there was no guarding or defending of the food source during any of the C.I.B. treatments, very low aggression was observed over the entire study and access to food by all individuals was apparent, which is contrary to previous studies (Belzung & Anderson, 1986; Bloomsmith & Lambeth, 1995; Ludes & Anderson, 1996; Young, 1997) that food presented in a localised manner (such as the C.I.B. treatments) produces these behaviours. A factor which could potentially be influencing this population's behaviour during feeding was the withdrawal from the food

source by all individuals once an appropriate quantity of food had been collected. This was assumed to be related to competition for the same item of food (most desirable foods) and retiring to a favourite consuming area, which was usually located high above the ground and away from all other individuals. Certainly, associations between aggressive behaviours and the continuous use of an enrichment device within a single place require further investigation. Also, there is no doubt that uncut food increases manual manipulation of dietary items (e.g. Kerridge, 2005), mainly due to the processing to an appropriate size, however, the processing has been shown (e.g. Kerridge, 2005) to influence the time spent foraging. Although, our observations suggest that uncut food presented randomly around the enclosure does not influence the time spent foraging intensely, the proportion of foraging events or the proportion of time spent foraging by capuchin monkeys, other primate species require further investigation.

Surprisingly, the capuchin monkeys showed varying behavioural patterns within the C.I.B. treatments. Indeed, there was evidence of a general increase over time for the foraging behaviour and similarly a general decline over time for locomotion and resting behaviours. These results seem to correspond with the other three treatments (i.e. C.A.E., U.A.E., and enrichment), with a general increase over time for the foraging behaviour and a general decline over time for locomotion and resting behaviours. This pattern of behaviour is believed to be due to uncontrollable factors, such as temperature (see Appendix 8), although alternating treatment effects cannot be excluded.

Management implications

Management plans for captive populations must account for the effect of severe changes in environment on animal welfare and psychological wellbeing. Once animals are introduced into a captive environment that does not resemble their natural environment, large stress-inducing factors can become apparent. One factor of particular concern is the alteration of behaviour patterns induced by a lack of stimulation.

The roles of a modern zoo/wildlife reserve are to conserve species, educate people, entertain the public and provide opportunity for scientific research (Tudge, 1992). The ultimate goals of a zoo or wildlife reserve are the welfare of the animals and their potential for reintroduction to their natural range through conservation efforts and actions. In order for the reintroduced individuals to have a high survival rate they must be genetically, physiologically and behaviourally the same as their wild conspecifics.

Environmental enrichment is commonly advocated as an effective method to improve psychological well-being of nonhuman primates and other mammals in captivity (Boinski *et al.* 1999). The ultimate goals of environmental enrichment are to promote species-typical behaviour and eliminate abnormal behaviour. The presentation of the diet is one particular area where application of ingenuity can be exercised to stimulate animals without compromising their health.

Preserving as much of a species foraging repertoire as possible seems particularly important in a captive setting where there are often limitations on other aspects of an animal's life, such as spatial or social limitations (Hayes, 1990). Interestingly, the different feeding treatments in this study affected the activity levels of the capuchins differently.

The period of intense foraging directly following feeding was shown to increase during the enrichment feeding treatment. Also, the number of events and the duration of foraging

increased during the enrichment feeding treatment. This increase in number of events and time allowed the capuchins to express increased interest in foraging and also allowed the population to display behaviour more inline with their wild conspecifics, e.g. increased foraging per day.

A reduction of resting, locomotion and abnormal behaviour was observed during the enrichment feeding treatment. Excessively raised resting and abnormal behaviour levels are generally undesirable as they can impact on conservation and reintroduction success. However, the U.A.E. feeding treatment may be correlated with both increased resting, decreased foraging and in theory induce weight loss compared to cut food in bowls feeding treatments. This technique could potentially be used to control animal weight, although further investigation is required.

The feeding treatments not only allowed the capuchins to display behaviour more in the range of their wild counterparts but also allowed them to express other desirable behaviours. For example, touch-dependent, tool-use dependent and manipulative-dependent foraging, which included using hammers and anvils to procure food, detection of non-visual food items, finding and using of sticks and cabbage tree leaves to excavate holes, pulling on ropes with their fore limbs while holding an object with their hind limbs, dissecting and manipulating fruits for mouth-size portions, and searching through a substrate to obtain food. These have been described for wild capuchin monkeys and were observed in this study.

All the feeding devices required more “wild” behaviours than was previously demanded of the animals. Additionally, each feeding device required different solutions for food to be obtained, which offered more diverse stimulation. Alternatively, the use of the novel devices on a rotational basis has been shown to increase their effect on the behaviour of the animals (Csatadi *et al.*, 2008; Paquette & Prescott, 1988; Visalberghi *et al.*, 2003).

Abiotic factors (e.g. temperature, precipitation etc.) are very important to identify as they have the potential to influence the behaviour of captive populations. In this study, temperature influenced the behaviour of the capuchin population immensely (Appendix 8). Temperature was also highly correlated with precipitation and visitor numbers. As temperature decreased from summer into winter, over treatment months, all behaviour in the visual field of the cameras declined i.e. behaviour was occurring out of sight of the cameras, either high in their enclosure or in their night den. Interestingly the behaviours of the capuchins were not influenced by the zookeeper.

The employment of foraging devices appeared to be a positive addition to the environment of these capuchins and provided an opportunity for foraging more towards appropriate time budgets for this species (Baldwin & Baldwin, 1977; Hayes, 1990). Results of this study were in agreement with those of previous studies showing that enrichment promotes behavioural time budgets more in line with wild conspecifics (Baker, 1997; Ludes & Anderson, 1996; Young, 1997) and elimination of abnormal behaviours (Mason, 1991; Shepherdson *et al.*, 1993; Young, 1997)

Enrichment

Primate species are surprisingly variable, particularly with respect to morphology, habitat, diet, and social organization, and would therefore be expected to vary in their response to environmental enrichment (Lutz & Novak, 2005). Enrichment methods can vary in complexity, such that a method that is optimal for one species may not be as beneficial for

another. Hence, any proposed environmental enrichment should consider the natural history of the species involved.

The ultimate goals of environmental enrichment are to promote species-typical behaviour and eliminate abnormal behaviour. There are several hypotheses about utilising enrichment devices for encouraging species-typical behaviour. First, the “usage” hypothesis, predicts that using an enrichment device requires species-typical behaviour (Lutz & Novak, 2005). For example, when monkeys are provided with foraging devices, foraging should increase and when monkeys are provided social contact, socialisation should increase. Second, the “normalised repertoire” hypothesis, predicts that the employment of enrichment helps normalise other aspects of the behavioural repertoire (Lutz & Novak, 2005). For example, the employment of a foraging device is predicted to alter other behaviours, through time budgets, in addition to those directly related to the enrichment device. Third, this hypothesis predicts that environmental enrichment reduces the occurrence of abnormal behaviour. Two additional hypotheses are concerned with abnormal behaviour: whether currently existing enrichment lowers levels of abnormal behaviour, and whether it prevents the behaviour (Lutz & Novak, 2005).

The first hypothesis predicts that using enrichment devices requires species-typical behaviours. The forage enrichment devices employed in this study did require the capuchins to display species-typical behaviours by causing increased foraging. Furthermore, the second hypothesis predicted that employment of enrichment helps normalise other aspects of the behavioural repertoire, which was displayed during the enrichment treatment in this study by reductions in locomotion and resting. Also, the third hypothesis predicts that environmental enrichment reduces the occurrence of abnormal behaviour, which was shown in this study with lowered levels of abnormal behaviour over the first three treatments and then elimination of any abnormal behaviour during the last three treatments. It is presumed that the reduction-elimination of abnormal behaviours during this study is associated with the increase in novelty during the feeding sessions and not the enrichment devices themselves. This presumption was established due to the first treatment with eliminated abnormal behaviour occurring during a cut food in bowls month, which was expected to show excessive abnormal behaviour.

Enrichment strategies can be divided into two general categories: providing the animals with inanimate forms of enrichment, and providing the animals with social contact (Lutz & Novak, 2005). Inanimate enrichment can be further divided into those that require some physical activity on the part of the animal (active enrichment) and those that provide only passive kinds of stimulation (Lutz & Novak 2005).

As with most zoological exhibits, animals are generally provided with social contact, and the population reported here is no exception. Social contact is usually an issue with individually housed animals, with primates it commonly occurs in biomedical laboratories (Fragaszy, *et al.*, 2004) and seldom occurs elsewhere. Therefore, it is not necessary to delve into social contact as an enrichment when the facilities where subjects requiring social contact reside usually have worse issues, such as space and animal welfare, which is associated with the reason why the individuals are being kept to begin with.

Primates in their wild environment spend a considerable amount of time searching and foraging for food, which is largely dependent on the quality of the environment. Given the substantial discrepancy in time budgets between wild and captive primates, providing foraging opportunities may substantially promote species-typical behaviour and improve the

well-being of captive primates (Lutz & Novak, 2005). Many devices and methods have been developed to achieve the goal of extending feeding time and complexity for captive primates, such as feeding balls, changes in substrate, puzzle feeders, etc., although these methods do not necessarily replicate foraging in the wild, they do simulate the process of working for food (Lutz & Novak, 2005). Due in part to increased processing time, simply feeding captive primates whole (vs. chopped) food has been shown to increase time spent feeding (Smith, *et al.*, 1989).

Capuchins are only a few of many species kept in zoos/wildlife reserves worldwide. This study is not focussed on capuchins per se but on the welfare and conservation of species in ex situ environments, and the principle of this study can be applied not only to other captive primates but also to other captive species. Similar studies on non-primate species have been conducted and resulted in similar findings. A study by Thorne *et al.* (2005) found that horses on a multiple forage diet performed foraging behaviour significantly more frequently and for significantly longer periods than horses on a single forage diet. Also, stereotypic weaving behaviour ceased to occur during the multiple forage diet. In another study, African elephants showed significant increases in feeding and species-typical behaviours and significant decreases in drinking and inactivity when hay was replaced with browse (mulberry (*Morus alba*), hackberry (*Celtis occidentalis*), oak species (*Quercus* spp) and bamboo (*Phyllostachys aurea*) (Stoinski *et al.*, 2001). These examples are but a few that employ environmental enrichment to elicit beneficial behaviours, eliminate abnormal behaviours and promote species-typical time-budgets. Therefore this study takes its place as a contributing document to environmental enrichment, primate research, capuchin behaviour and most of all the welfare and conservation of ex situ populations. The capuchin species of this study is not threatened in its native environment, but this research shows that welfare and conservation of other species, in an ex-situ captive environment, may allow the opportunity to display species-typical behaviours, prior to any reintroduction attempt. Abnormal behaviours seem to persist in captive environments, but with the introduction of enrichment devices, this research has shown that abnormal behaviours have been replaced with species-typical behaviours. Therefore, if reintroduction is an objective for a holding institution, environmental enrichment should be a mandatory requirement for the captive species.

The research reported in this thesis has contributed to the knowledge of primate behaviour with enrichment. The results of the different treatments indicated that some enrichment strategies do not significantly influence the behaviour of this population. The cut and uncut food presented around the enclosure did not appear to have significant influences on the capuchins behaviour. The results reported here for the enrichment treatment support the view that environmental enrichment can promote species-typical behaviour (e.g. Hayes, 1990), display reductions or eliminate compensatory, abnormal or stereotypical behaviours (e.g. Anderson & Chamove, 1984), increase foraging (e.g. Hayes, 1990; Kerridge, 2005; Voelkl, *et al.*, 2001), reduce the occurrence of resting (e.g. Anderson & Chamove, 1984; Maloney, *et al.* 2006; Sommerfeld, *et al.* 2005; Voelkl, *et al.* 2001) and increase the manual manipulation of dietary items (e.g. Anderson & Chamove, 1984; Kerridge, 2005). Therefore, the results from this research provide excellent support for the hypothesis that environmental enrichment promotes increased beneficial behaviours.

Relevance of this research

The application of the methodology reported here may be confounded in other studies by the lack of free-ranging abilities that some capuchin populations exhibit. Scaling the sizes of the devices in proportion to the number of individuals present may overcome this problem,

although capuchins kept in confined cages, such as commonly reported in biomedical research facilities (Fragaszy *et al.*, 2004) may find that the space is too confined for any further additions.

The use of these devices for other primate species may not work as effectively as in this study due to the design of the devices. The devices were designed to incorporate certain dependant features of the capuchins behaviour and abilities, some of which (e.g. manipulative propensities), other primates (e.g. lemurs) show little of (van Schaik *et al.*, 1999). Accordingly, primates exhibiting tool use and complex manipulation (e.g. species in the genera *Gorilla*, *Macaca*, *Papio*, *Pan*, *Pongo* etc.; van Schaik *et al.*, 1999) are presumed to similarly benefit from these enrichment devices.

Certainly, the New Zealand environment where this research was conducted shows no significant effect (in relation to other studies) on the behaviour of this species under environmental enrichment. Accordingly, this research can be used as a reference not only for other capuchin populations worldwide but particularly for populations kept in a temperate environment. Also, the research presented here provides a sound foundation for further work, both domestically and internationally. Robust primate studies in New Zealand are very rare, this thesis may contribute to further studies in New Zealand and in other temperate countries.

Future research

On 20th August 2008 the population of capuchins in this study were transferred to a new enclosure. The new enclosure has a large amount of vegetation and fronts onto a large pond (see Appendix 9). Future research, using similar methods to this study, will be confounded by the large proportion of vegetation and little to no area to set up a camera. The new enclosure appears to be an enhanced habitat, from that of the studied enclosure, with a more naturalistic environment and a more suitable night den (temperature regulated and insulated).

Early-mid 2009 all four male capuchins are expected to be exchanged for males from Franklin zoo, Tuakau, New Zealand (K. Willis, pers. comm., 20 August 2008). The females at Willowbank Wildlife Reserve will be put on contraception until the new males arrive from Franklin zoo (K. Willis, pers. comm., 20 August 2008). This exchange is critically required for gene pool of Willowbank's population and may provide advantageous for the longevity of both populations.

A comparative study on the capuchin behaviour while residing in their new enclosure at Willowbank would be very interesting and could show how the environment effects capuchin behaviour and also show how to further enhance the environment. If this study is to be replicated then perhaps consideration should be made to the quantity and quality of food that each device is allocated. Also, the relation between uncontrollable factors and the behaviour of capuchins appears to be very intricate and requires further acknowledgement when future research is conducted.

Little effect of the C.A.E. treatment was apparent, however, some indirect effects of the U.A.E. treatment were observed. Research into the indirect effects of the U.A.E. treatment could provide some interesting outcomes. Also, research on the affect of the U.A.E. treatment on other primate species may provide some answers. Further investigation into the interactions between the C.I.B. treatments and the C.A.E., U.A.E. and enrichment treatments is required to establish any cross-over effects. Investigating the potential of the U.A.E.

feeding treatment inducing weight loss is suggested. This technique could potentially be used to control the capuchin's weight.

Associations between aggressive behaviours and the continuous use of an enrichment device within a single place requires further investigation as the results of this study are contrary to previous studies that food presented in a localised manner (such as the C.I.B. treatments) produces these behaviours. Perhaps a single enrichment device presented in a localised manner provides the same stimulation as when animals are fed in bowls (particularly as novelty dilapidates). Also, a way of identifying each capuchin to establish individual benefits associated with enrichment could be accomplished by marking the animals prior to any study or using higher resolution cameras.

Recommendations

Willowbank Wildlife Reserve should persist with the enrichment of the capuchins using novel foraging devices for several reasons. First, the psychological wellbeing of the animals is at risk, and novel foraging devices appear to stimulate them while potentially reducing the rate of escape. Second, such enrichment may prevent or delay the destruction of the new habitat, in particular the vegetation (of which their old enclosure had none) and enclosure structure. Third, it may prevent the occurrence of compensatory, abnormal or stereotypical behaviours; promote appropriate behaviours and species-typical time-budgets.

Inbreeding of the capuchin population at Willowbank Wildlife Reserve is a serious problem and possibly contributes to the cause of the severe infant mortality before and during this study. The exchange in males between Willowbank Wildlife Reserve and Franklin zoo should be considered as a mandatory requirement, rather than a suggestion, for further breeding and viable offspring.

The new enclosure of the capuchins should not be allowed to degrade to the standard of the old enclosure. Stimulation of the capuchins through providing enrichment is suggested, not just foraging devices but also objects that allow expression of wild behaviours, which they will ultimately participate in while in the new enclosure and the vegetation is still present. Such as providing large logs so that they can strip off the bark, making crevices where touch-dependency is required, providing toys with manipulative-dependent features and ultimately providing an environment that stimulates them as long as physically and mentally possible.

Conclusions

The introduction of enrichment feeding devices enhances this particular population's behaviour more in line with their wild conspecifics by lowering the time spent and frequency of events in resting and locomotion. The box feeding device and the straw foraging area were utilised more (in both number of events and duration) than the drilled wood logs and Kong®'s.

Few direct beneficial effects were observed during the C.A.E. and U.A.E. feeding treatments. The proportion of time spent resting showed that the U.A.E. feeding treatment was relatively high, however this may be correlated with the difficulty of obtaining food and possibly indirectly correlated with weight loss. The C.I.B. treatments may have been influenced by temperature or possibly by the other alternating treatments. Temperature, precipitation and visitor numbers all seem to be correlated and may influence the behaviour of the population.

Only some abnormal behaviour was observed during the first three treatments and ceased to exist during the last three treatments. Abnormal behaviour in the form of guarding of food and aggressive behaviour was not observed in this study.

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Special thanks to my supervisors, Adrian Paterson and James Ross for their advice, editing and supervising a project that was a little bit different!! Without their supervision I would have never completed this unique thesis.

Also, thanks again to James Ross for his methodological and statistical abilities.

Special thanks to Willowbank Wildlife Reserve staff- with particular reference to Monique van der Linden- Hagedoorn (without her effort, cooperation and persistence, this project would not have got off the ground), Sofie Hunt, Stacy Hobson, Bella Murphy and Anna Columbus (also thanks for cooperation in feeding regimes during the six months), Michael Willis and Jeremy Magure (owner and manager – thanks for this opportunity).

Cheers to the capuchin monkeys for opening my eyes.

Appendix 1

Cebus apella held in zoos monitored by the International Species Information System (ISIS).

***Cebus apella* held in zoos monitored by the International Species Information System (ISIS) (data from ISIS, 09 July, 2008).**

	Male	Female	Unknown Births (last 12 months)	Total
<i>Cebus apella xanthosternos</i> <<< Group >>>				13
Monk capuchin				
Range: RIO DE JAN-BAHIA BRAZIL				
<i>Cebus apella xanthosternos</i>	62	38	6	8 114
Monk capuchin				
Range: RIO DE JAN-BAHIA BRAZIL				
<i>Cebus apella trinitatis</i> <<< Group >>>				2
White-fronted capuchin				
Range: TRINIDAD				
<i>Cebus apella trinitatis</i>	1			1
White-fronted capuchin				
Range: TRINIDAD				
<i>Cebus apella robustus</i>	5	6	1	1 13
Crested capuchin				
Range: S BAHIA-RIO D JANEIR BRAZ				
<i>Cebus apella nigrinus</i>	2	1		3
Tufted capuchin				
Range: SOUTHEASTERN BRAZIL				
<i>Cebus apella macrocephalus</i>	3			3
Large-headed capuchin				
Range: SOUTH AMAZON,BRAZIL				
<i>Cebus apella cay</i>	14	26	1	41
Hooded capuchin				
Range: N PARAGUAY,S MATO GROSSO				
<i>Cebus apella apella</i> <<< Group >>>				8
Brown capuchin				
Range: GUIANAS,NORTHERN BRAZIL				
<i>Cebus apella apella</i>	40	18	3	5 66
Brown capuchin				
Range: GUIANAS,NORTHERN BRAZIL				
<i>Cebus apella</i> <<< Hybrid >>>	11	18	4	33
Brown capuchin				
Range: COLOMBIA,VENEZUELA-NORTH ARGENTINA				
<i>Cebus apella</i> <<< Group >>>				36
Brown capuchin				
Range: COLOMBIA,VENEZUELA-NORTH ARGENTINA				
<i>Cebus apella</i>	245	237	53	21 556
Brown capuchin				

Range: COLOMBIA,VENEZUELA-NORTH ARGENTINA

	Male	Female	Unknown	Births (last 12 months)	Total
TOTAL <i>Cebus apella</i>	383	344	68	35	889

Appendix 2

Historical genetic records of capuchins at Willowbank Wildlife Reserve (only individuals surviving).

Historical genetic records of capuchins at Willowbank Wildlife Reserve (only individuals surviving)

Female	Contributing Male	Offspring
Cappy (F.born 1965, arrived 1975)	Sundance (M.arrived 1977)	Bam bam (F. born 1979)
	Sundance (M.arrived 1977)	Koru (F.born 1980)
	Sundance (M.arrived 1977)	Patrick (M.born 1981)
	Sundance (M.arrived 1977)	Unknown (born 1983)
	Sundance (M.arrived 1977)	Houdini (M.born 1988)
	Sundance (M.arrived 1977)	Survivor (M.born 1990)
	Sundance (M.arrived 1977)	Little one (born 1991)
	Sundance (M.arrived 1977)	Spiderman (M.born 1993)
unknown	unknown	Buddy (M. born 1995)
Bam bam (F. born 1979)	Sundance (M.arrived 1977)	Mask (M.born 1991)
	Sundance (M.arrived 1977)	Trixie (F.born 1993)
	Mr Flick aka E.T. (M. born 1990)	Rebel (M.born 1995) aka Grumpy?
Koru (F.born 1980)	Sundance (M.arrived 1977)	Mr Flick aka E.T. (M. born 1990)
	Sundance (M.arrived 1977)	Button (born 1992)
Hope (F.born Wellington 1984, arrived 1990)	Survivor (M.born 1990)	Lucky (M.born 1998)
	Survivor (M.born 1990)	Sunny (M. born 1999)
Pam (F. born ?)	Mr Flick aka E.T. (M. born 1990)	Johnny (M. born 2007)
???	Mr Flick/Grumpy?	Paris (F. born 2006)
???	Mr Flick/Grumpy?	Ben (M. born 2004)
Cessarian (F. born?)	Mr Flick aka E.T. (M. born 1990)	died by cessarian
New alpha (F. born?)	Mr Flick aka E.T. (M. born 1990)	Not yet named (? . Born 2008)
Unknown (F. born ?)		
Unknown (F. born ?)		
	departed for Thailand	
	current population	

Appendix 3

Recognised species and subspecies in the Genus *Cebus*, their IUCN status and naming authorities.

Recognised species and subspecies in the Genus *Cebus*, their IUCN status and naming authorities.

Species	Subspecies	Common Name	IUCN Status	Authority
<i>Cebus albifrons</i> ²	<i>albifrons</i> ^{*1}	White-fronted capuchin	Least Concern	Humboldt, 1812
	<i>aequatorialis</i> ^{*1}	Ecuadorian capuchin	Near Threatened	Allen, 1914
	<i>malitiosus</i> ¹		Near Threatened	Elliot, 1909
	<i>cesarae</i> ¹		Near Threatened	Hershkowitz, 1949
	<i>yuracus</i> ¹	Andean white-fronted capuchin	Data Deficient	Hershkowitz, 1949
	<i>versicolor</i> ^{*1}	Varied capuchin	Data Deficient	Pucheran, 1845
	<i>cuscinus</i> ^{*1}	Sock/headed capuchin	Least Concern	Thomas, 1901
	<i>trinitatis</i> ^{*1}	Trinidad white/fronted capuchin	Critically endangered	Von Pusch, 1941
	<i>unicolour</i> [*]			Spix, 1823
<i>Cebus apella</i> ²	<i>apella</i> ^{*1}	Guianan brown capuchin	Least Concern	Linnaeus, 1758
	<i>margaritae</i> ^{*1}	Margarita island capuchin	Critically endangered	Hollister, 1914
	<i>fatuellus</i> [*]			Linnaeus, 1766
	<i>macrocephalus</i> [*]			Spix, 1823
	<i>peruanus</i> [*]			Thomas, 1901
	<i>tocantinus</i> [*]			Lönnberg, 1939
<i>Cebus capucinus</i> ^{*2}	<i>capucinus</i> ¹	White-faced capuchin	Least Concern	Linnaeus, 1758
	<i>curtus</i> ¹	Gorgona white/fronted capuchin	Vulnerable	Bangs, 1905
	<i>limitaneus</i> ¹		Least Concern	Hollister, 1914
	<i>imitator</i> ¹	Panamanian white/throated capuchin	Least Concern	Thomas, 1903
<i>Cebus macrocephalus</i> ¹	-	Large-headed capuchin	Least Concern	Spix, 1823
<i>Cebus olivaceus</i> ^{*2}	<i>olivaceus</i> ¹	Wedge-capped capuchin	Least Concern	Schomburgk, 1848
	<i>apiculatus</i> ¹		Least Concern	Elliot, 1907
	<i>castaneus</i> ¹	Chestnut capuchin	Least Concern	Geoffroy, 1851
	<i>kaapori</i> ¹	Ka'apor capuchin	Vulnerable	Queiroz, 1992
	<i>brunneus</i> ¹	Brown weeper capuchin	Least Concern	Allen, 1914
	<i>nigrivittatus</i> ¹		Least Concern	Wagner, 1848
<i>Cebus robustus</i> ¹	-	Crested capuchin	Vulnerable	Kuhl, 1820
<i>Cebus xanthosternos</i> ^{*12}	-	Yellow-breasted capuchin	Critically endangered	Wied-Neuwied, 1826
<i>Cebus kaapori</i> ^{*2}	-	Kaapori capuchin		Queiroz, 1992
<i>Cebus libidinosus</i> ²	<i>libidinosus</i> [*]	Black-striped tufted capuchin		Spix, 1823
	<i>pallidus</i> [*]			Gray, 1866
	<i>paraguayanus</i> [*]			Fischer, 1829
	<i>juruanus</i> [*]			Lönnberg, 1939
<i>Cebus nigratus</i> ²	<i>nigratus</i> [*]	Black-tufted capuchin		Goldfuss, 1809
	<i>cucullatus</i> [*]			Spix, 1823
	<i>robustus</i> [*]			Kuhl, 1820
<i>Cebus queirozi</i> ³	-	Blonde capuchin	Expected critically endangered	Mendes Pontes and Malta, 2006

^{*}Groves, 2005, ¹ IUCN redlist, 2007, ² UNEP-WCMC CITES Appendix 2, 2008, ³ Pontes & Malta, 2006.

Appendix 4

Captive diet (spread over two feeding sessions) of the capuchins at Willowbank Wildlife Reserve.

Captive diet (spread over two main meals):

Item	Mon	Tues	Wed	Thurs	Fri	Sat	Sun
Apples	12	12	12	12	12	12	12
Bananas	16	16	16	16	16	16	16
Bread (slices)	14	14	14	14	14	14	14
Carrot	4		4		4		4
Cheese	200g		200g		200g		
Boiled eggs	8		8		8	8	
Grapes	70		70		70		70
Pears		4		4		4	
Cooked rice*	300g		300g		300g		
Sultanas	1 hand		1 hand		1 hand		1 hand
Peanuts				2 hands		1 hand	
Spinach / Celery	2	1	2	1	2	1	2
Oranges		8		8		8	
Kiwifruit	8		8		8		8
Cooked potatoes	6		6		6		

Appendix 5

Primate pellet ingredients.

10 March 2008

Primate Pellets

Hi Paul,

Following our telephone conversation on Dunstan Primate Pellets, details below:

Ingredients – Maize, Soya Meal Extracted, Soya Meal Full Fat, Casein, Limestone, Dicalcium Phosphate, Soya Oil, Salt, Lysine, Minerals and Vitamins – Sweetner

Analysis As Fed 90% Dry Matter

Crude Protein 22%

Lysine 1.4%

Fat 5.5%

Fibre 3.5%

Salt 1.0%

Calcium 0.7%

Phosphorus 0.5%

Trace Minerals & Vitamins as used in the nutrition of cats and dogs.

Im no expert in Primate nutrition Paul, if in your studies you come across anything I should be adding I would be grateful for your advice.

Volumes are extremely small but nevertheless would always want to ensure a diet that meets requirements.

If I can be of any assistance, please do not hesitate to make contact

Kind Regards

Chris Whalley
Nutritionist

Appendix 6

Permit and ethics approval for working with primates at Willowbank Wildlife Reserve.



Lincoln University
Te Whare Wānaka o Aoraki

Bio-Protection and Ecology Division

PO Box 84, Lincoln University,
Lincoln 7647, Canterbury, New Zealand

Telephone 64 3 325-2811
Facsimile 64 3 325-3844

www.lincoln.ac.nz/bpec
Email bpec@lincoln.ac.nz

Letter seeking permission to conduct research at Willowbank Wildlife Reserve by Lincoln University

This Letter is only for use between Lincoln University and Willowbank Wildlife Reserve interested in a joint collaborative research study.

As part of awarding the Master in International Nature Conservation (MINC), at Lincoln/Göttingen Universities, each applicant is required to complete a one year research thesis.

Lincoln University (PO Box 84, Lincoln, Christchurch, New Zealand) wish to enter an investigation into whether forage enrichment promotes increased activity in captive *Cebus apella*. The Principal Investigator and who is responsible for the direction and conduct of the study under the auspices of Willowbank Wildlife Reserve is Paul Dutton at Lincoln University.

All other details will be agreed upon via verbal exchange.

Name: Wendy A. Dutton

Signature: [Signature]

Date: 9-01-08

Name: Paul Dutton

Signature: [Signature]

Date: 09/01/08



Lincoln University
Te Whare Wānaka o Aoraki

Research & Innovation Office
P O Box 94
Lincoln University
Canterbury 8150
NEW ZEALAND
Telephone 64 03 325 2811
Fax 64 03 325 3630

4 December 2007

Dr Adrian Paterson
Bio-Protection & Ecology Division

Dear Adrian

Re: Application to Animal Ethics Committee - #224

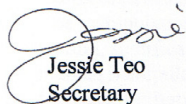
The Lincoln University Animal Ethics Committee (AEC) recently considered an application from you. It was approved and a copy of the version held on the University files is enclosed.

Application for Animal Ethics Approval No. 224: Does forage enrichment promote increased activity in captive *Cebus paella* at Willowbank Wildlife Reserve?

Approved

[Note. It is assumed that you will inform the proprietors of Willowbank Wildlife Reserve about this decision and the details of the research project.]

Yours sincerely



Jessie Teo
Secretary
Animal Ethics Committee

Encl: #224

Appendix 7

Purposefully designed printed spreadsheet for raw records of capuchin behaviours.

Purposefully designed printed spreadsheet for raw records of capuchin behaviours.

Date: _____

Camera:

Session: _____

[illegible]

Appendix 8

Results of the initial analysis with abiotic factors.

Results with abiotic factors

The following set of results was produced from an analysis of the observation data with the inclusion of abiotic factors (temperature and precipitation) and visitor numbers. There was a correlation between these factors and also a correlation of these factors with the behaviour of the capuchin monkeys over time.

These set of results differ to that in the results section of the main body of the thesis by the influence of temperature, precipitation and visitor numbers on the behaviour of the capuchin monkeys during the study period. A reduction in all activity was observed as the study moved into winter. If this data was to be used then the feeding treatments presented in winter would have been under-reported as all behaviour was decreased with declining temperatures. The analysis used in the main thesis examines just the change in behaviour exhibited corrected for season.

The means of the data (non-transformed count and duration data) were analysed to produce this set of results with general linear modelling with poisson error distribution for the count data and normal error distribution for the duration data. These were analysed against the variables: treatment, temperature, precipitation and time + visitors, which produced the decrease in activity over time (as the study moved into winter).

Foraging (count) as a whole

For foraging count there was a significant treatment effect ($F_{5,389}=7.19$, $P<0.001$). Multiple comparisons (using Fishers Protected 5% LSD) of treatment means indicated that the enrichment and C.I.B.3 treatments were significantly lower than the other treatments (Figure 3.2). The C.I.B.3 treatment was also significantly lower than the enrichment treatment. Analysis of temperature and visitor numbers was also statistically significant ($F_{1,389}=5.75$, $P<0.017$ and $F_{1,389}=4.72$, $P<0.030$ resp.), with a tendency for decreased foraging as temperature and visitor numbers increased. However, there was not a significant difference in the time of day ($F=1.22$, $P>0.05$) and precipitation rate ($F=0.56$, $P>0.05$).

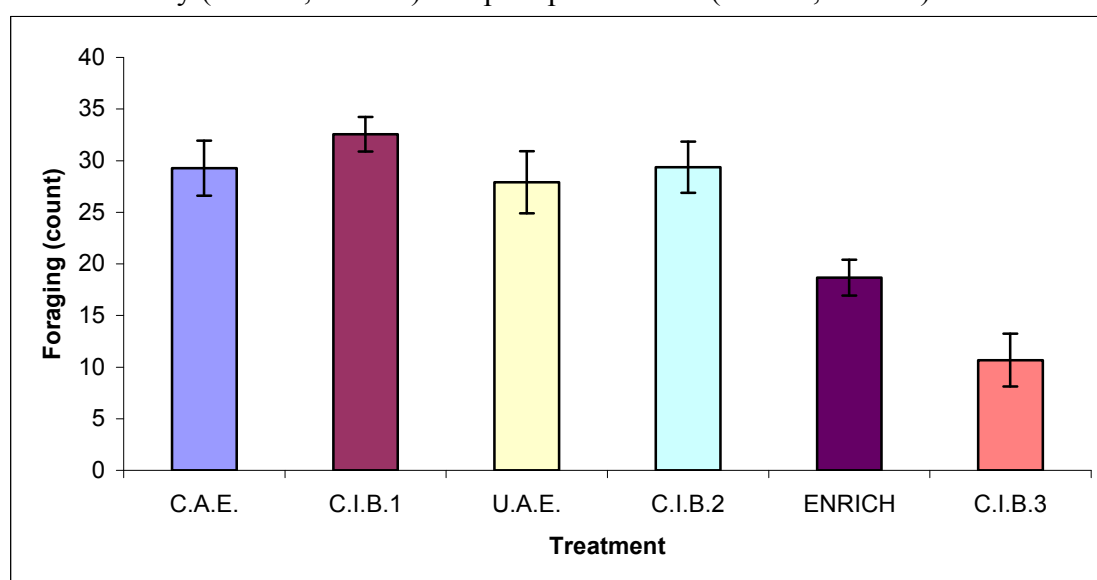


Figure 3.2. Count of foraging events by capuchins between different treatments (\pm SEM).

Foraging (duration)

Foraging duration (sec.) showed similar results to foraging count with significant treatment effect ($F_{5,389}=3.67$, $P<0.003$). Multiple comparisons (using Fishers Protected 5% LSD) of treatment means indicated that the enrichment and C.I.B.3 treatments were significantly lower than the other treatments (Figure 3.3). Statistical analysis of mean temperature was also significant ($F_{1,389}=5.24$, $P<0.023$). Also, there was no significant difference in the visitor numbers ($F=3.80$, $P>0.05$), time of day ($F=1.43$, $P>0.05$) and precipitation rate ($F=2.22$, $P>0.05$).

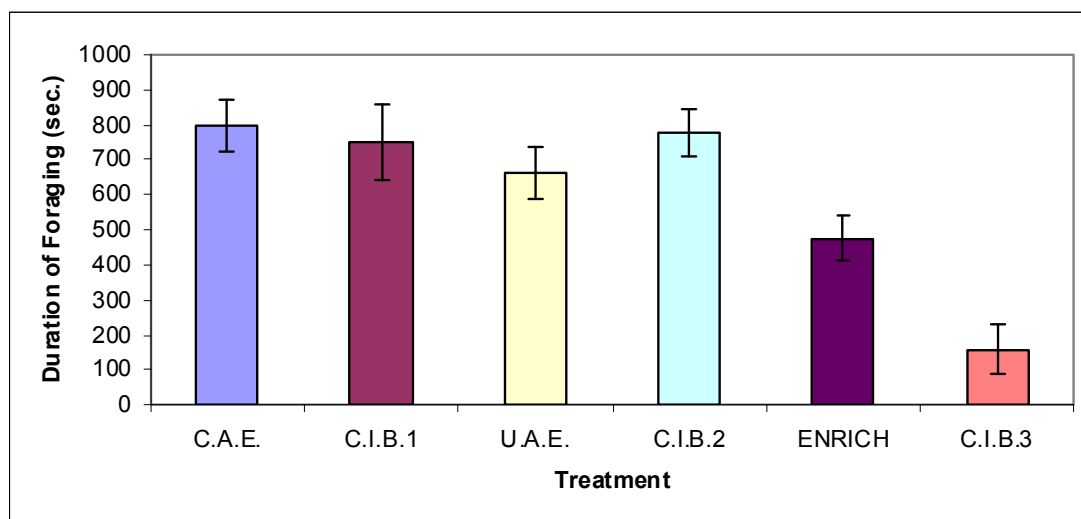


Figure 3.3. Duration of foraging behaviour by capuchins between different treatments (\pm SEM).

Foraging (mean)

For mean foraging there was a significant treatment effect ($F_{5,389}=3.94$, $P<0.002$). Multiple comparisons of the treatment means indicated that the enrichment treatment was significantly lower than the previous four treatments. However, the C.I.B.3 treatment was not significantly lower to the enrichment treatment (as observed in the count and duration models). The U.A.E. treatment was significantly lower to the C.A.E. and C.I.B.2 treatments and significantly higher to the enrichment treatment.

Also, there was a significant precipitation effect ($F_{1,389}=24.63$, $P<0.001$), however visitor numbers showed no significant effect ($F=3.72$, $P>0.05$). Mean foraging was observed to reduce as precipitation increased.

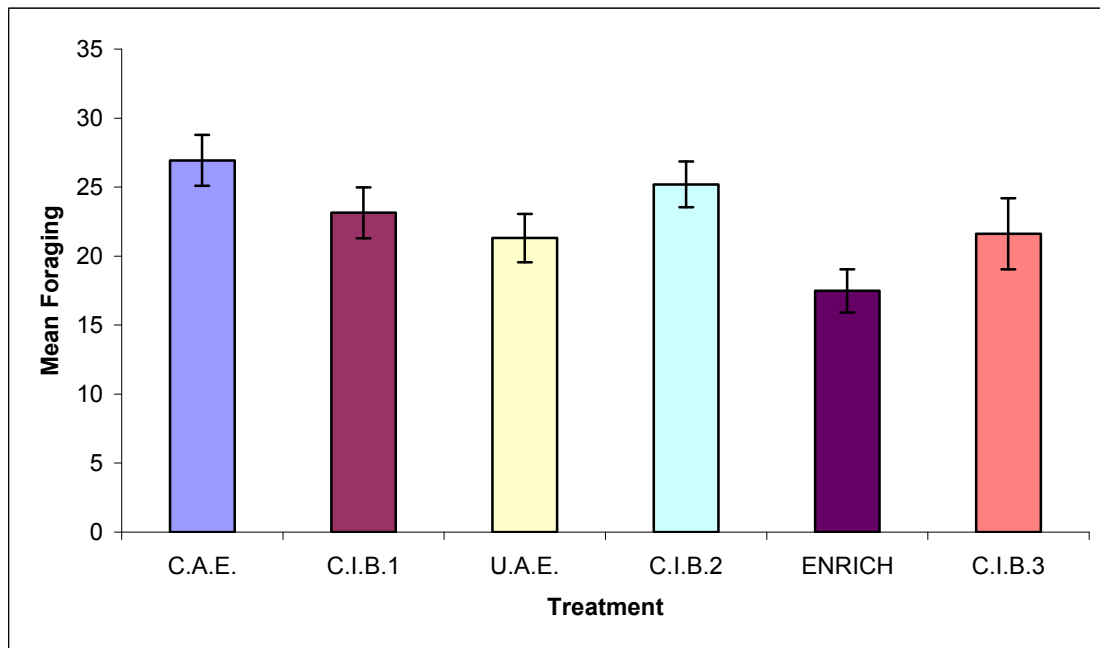


Figure 3.4. Mean foraging events of capuchins between different treatments (\pm SEM).

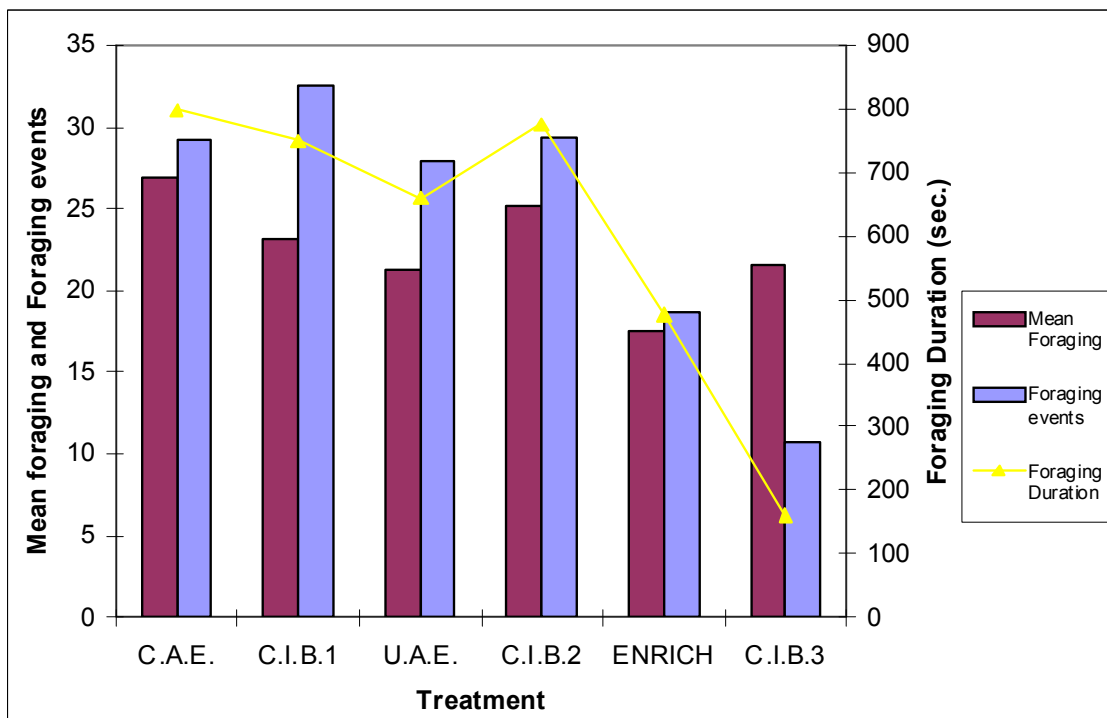


Figure 3.5. Mean foraging, foraging events and foraging duration

Locomotion (count)

There was a significant treatment effect for locomotion count ($F_{5,389}=23.21$, $P<0.001$). Multiple comparisons (using Fishers Protected 5% LSD) of the treatment means indicated that C.I.B.2, enrichment and C.I.B.3 treatments were significantly lower than the other treatments (Figure 3.5).

Although the enrichment and C.I.B.3 treatments were not significantly different, they were significantly lower than C.I.B.2 treatment (i.e. C.I.B.2 treatment was significantly different to

all other treatments). Also, there was a significant effect of time ($F_{1,389}=8.08$, $P<0.005$) on locomotion count. The feeding session (a.m./ p.m.) in the morning displayed significantly higher locomotion (count) than the afternoon session. Temperature, precipitation and visitor numbers showed no significant effect on the count of locomotion ($F=2.97$, $P>0.05$, $F=3.09$, $P>0.05$, $F=0.41$, $P>0.05$ resp.).

Locomotion (duration)

For the duration of locomotion there was a significant treatment effect ($F_{5,389}=35.77$, $P<0.001$). Multiple comparisons of the treatment means indicated that C.I.B.2, enrichment and C.I.B.3 treatments were significantly lower than the other treatments (Figure 3.6).

Although the enrichment and C.I.B.3 treatments were not significantly different, they were significantly lower than C.I.B.2 treatment (i.e. C.I.B.2 treatment was significantly different to all other treatments). The U.A.E. treatment was significantly lower than the C.A.E. treatment and significantly higher than C.I.B.2, enrichment and C.I.B.3 treatments. Also, there was a significant effect of time ($F_{1,389}=6.14$, $P<0.014$) on the duration of locomotion. The feeding session (a.m./ p.m.) in the morning displayed significantly higher locomotion (count) than the afternoon session. Temperature, precipitation and visitor numbers showed no significant effect on the count of locomotion ($F=0.16$, $P>0.6$, $F=1.81$, $P>0.17$, $F=1.44$, $P>0.23$ resp.).

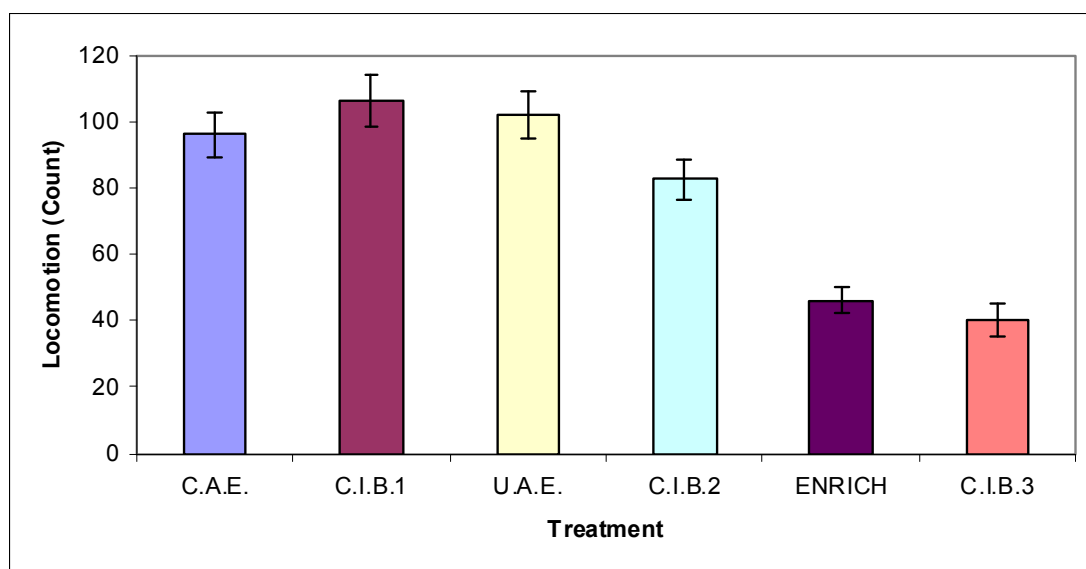


Figure 3.5. Count of locomotion behaviour (\pm SEM) by capuchins under the influence of different treatments.

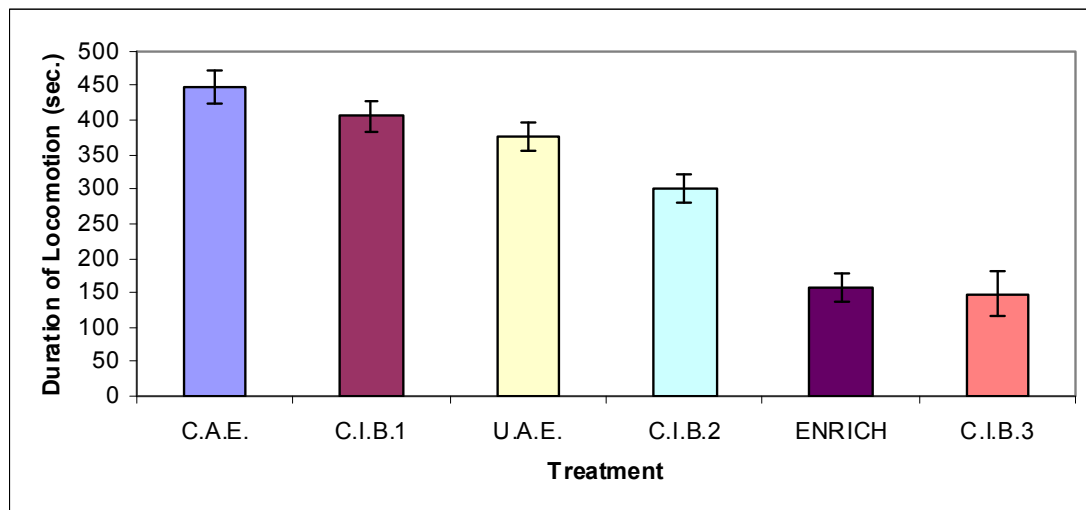


Figure 3.6. Duration (sec.) of locomotion (\pm SEM) by capuchins between different treatments.

Mean locomotion

There was also a significant treatment effect ($F_{5,389}=31.10$, $P<0.001$) for mean locomotion. Pairwise comparisons (using Fishers Protected 5% LSD) of treatment means indicated that the C.A.E. treatment was significantly higher than all other treatments. Also, the enrichment treatment was significantly lower than all other treatments. Temperature and visitor numbers also showed significant effects on mean locomotion ($F_{1,389}=10.14$, $P<0.002$, $F_{1,389}=8.69$, $P<0.003$). Mean locomotion decreased as temperature and visitor numbers increased. Precipitation and time showed no significant effect ($F=2.57$, $P>0.05$, $F=0.34$, $P>0.05$ resp.)

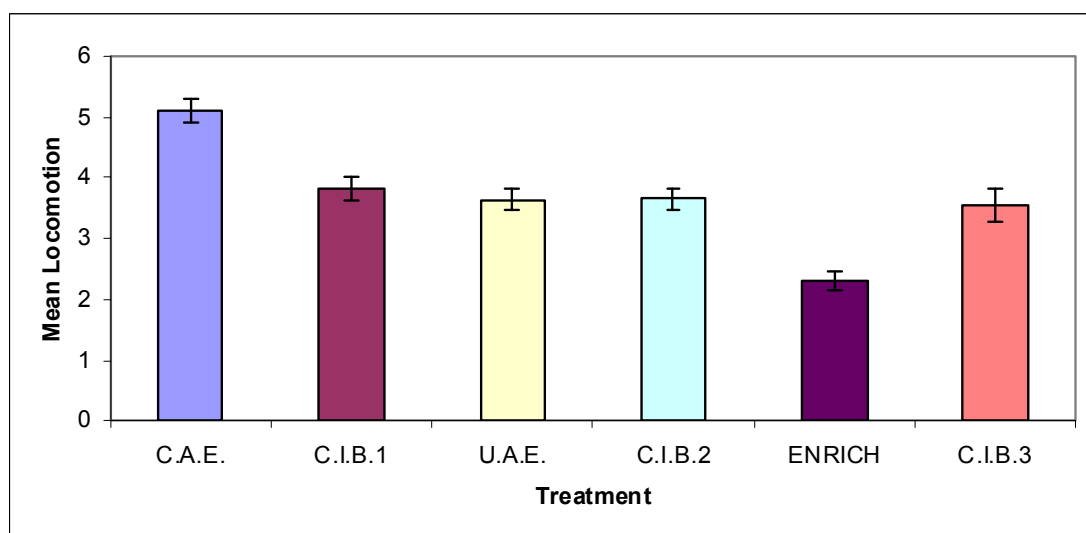


Figure 3.7. Mean locomotion (\pm SEM) of capuchins between different treatments.

Resting (count)

For resting count there was a significant treatment effect ($F_{5,389}=29.56$, $P<0.001$). Pairwise comparisons of the treatment means indicated that C.A.E. and C.I.B.2 treatments were significantly lower than C.I.B.1 and U.A.E. treatments and significantly higher than enrichment and C.I.B.3 treatments. C.I.B.1 and U.A.E. treatments were not significantly

different from one another, along with C.A.E. and C.I.B.2 treatments; however, the enrichment treatment was significantly higher than the C.I.B.3 treatment. Precipitation showed a significant effect ($F_{1,389}=4.75$, $P<0.030$) on resting count. Temperature, visitor numbers and time (a.m./ p.m.) showed no significant effect ($F=2.81$, $P>0.09$, $F=0.14$, $P>0.71$, $F=2.41$, $P>0.12$ resp.) on resting count.

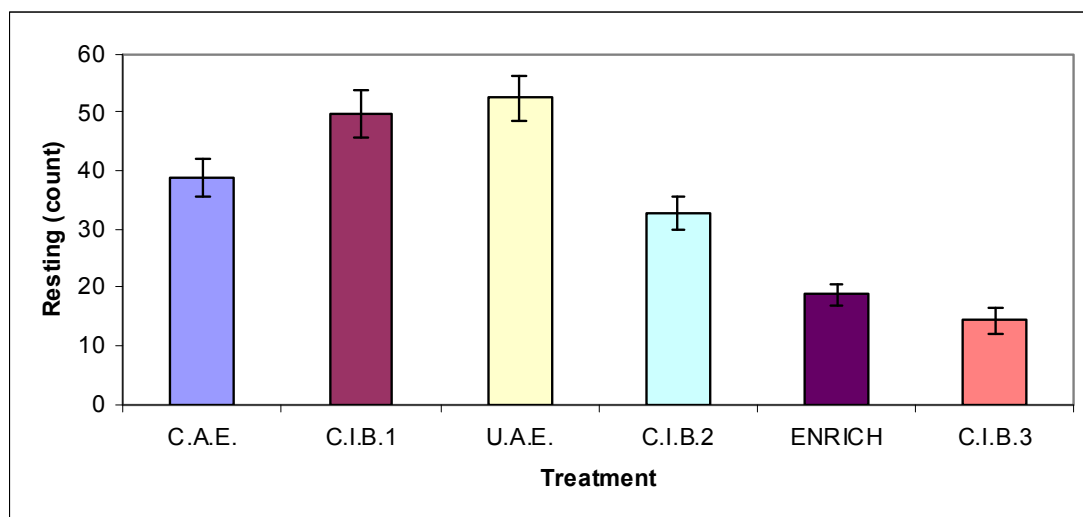


Figure 3.8. Count of resting behaviour (\pm SEM) of capuchins under different treatments.

Resting (duration)

There was a significant treatment effect for the duration of resting ($F_{5,389}=11.29$, $P<0.001$). Pairwise comparisons of the treatment means indicated that there was no significant difference between C.A.E., C.I.B.1 and U.A.E. treatments. The C.I.B.2 treatment was not significantly different to the C.A.E. treatment, however was significantly lower than C.I.B.1 and U.A.E. treatments. The enrichment and C.I.B.3 treatments were not significantly different from one another, but were significantly lower than all other treatments. Temperature, precipitation, visitor numbers and time of feed showed no significant effects on the duration of resting ($F_{1,389}=2.96$, $P>0.05$; $F_{1,389}=0.5$, $P>0.05$; $F_{1,389}=0.06$, $P>0.05$; $F_{1,389}=0.67$, $P>0.05$ resp.)

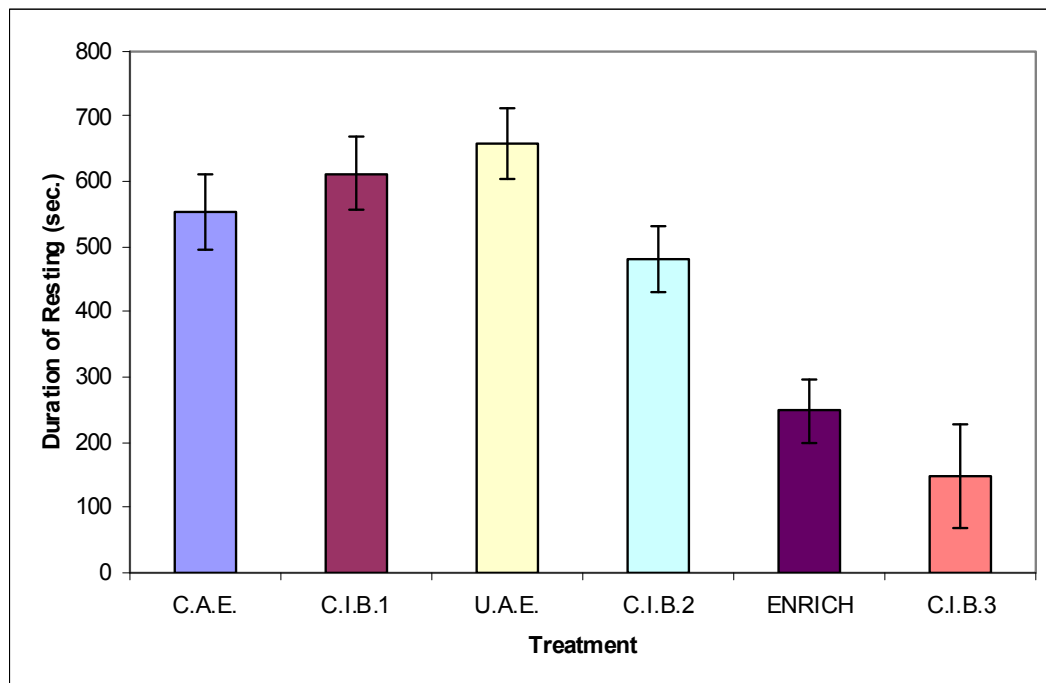


Figure 3.9. Duration of resting behaviour (\pm SEM) by capuchins over varying feeding treatments

Summary of results

Foraging count

- For foraging count there was a significant treatment effect ($F_{5,389}=7.19$, $P<0.001$).
- The enrichment and C.I.B.3 treatments were significantly lower than the other treatments.
- Temperature and visitor numbers were also statistically significant ($F_{1,389}=5.75$, $P<0.05$ and $F_{1,389}=4.72$, $P<0.05$ resp.).
- No significant difference in the time of day ($F=1.22$, $P>0.05$) and precipitation rate ($F=0.56$, $P>0.05$).

Foraging duration

- Significant treatment effect ($F_{5,389}=3.67$, $P<0.005$).
- The enrichment and C.I.B.3 treatments were significantly lower than the other treatments.
- Statistical analysis of mean temperature was also significant ($F_{1,389}=5.24$, $P<0.05$).
- There was no significant difference in the visitor numbers ($F=3.80$, $P>0.05$), time of day ($F=1.43$, $P>0.05$) and precipitation rate ($F=2.22$, $P>0.05$).

Foraging mean

- Significant treatment effect ($F_{5,389}=3.94$, $P<0.005$).
- The enrichment treatment was significantly lower than the previous four treatments.
- There was a significant precipitation effect ($F_{1,389}=24.63$, $P<0.001$), however visitor numbers showed no significant effect ($F=3.72$, $P>0.05$).

Locomotion count

- Significant treatment effect for locomotion count ($F_{5,389}=23.21$, $P<0.001$).
- C.I.B.2, enrichment and C.I.B.3 treatments were significantly lower than the other treatments.
- There was a significant effect of time ($F_{1,389}=8.08$, $P<0.005$) on locomotion count.

- Temperature, precipitation and visitor numbers showed no significant effect on the count of locomotion ($F=2.97$, $P>0.05$, $F=3.09$, $P>0.05$, $F=0.41$, $P>0.05$ resp.).

Locomotion duration

- There was a significant treatment effect ($F_{5,389}=35.77$, $P<0.001$).
- C.I.B.2, enrichment and C.I.B.3 treatments were significantly lower than the other treatments.
- There was a significant effect of time ($F_{1,389}=6.14$, $P<0.01$) on the duration of locomotion.
- The feeding session (a.m./ p.m.) in the morning displayed significantly higher locomotion (count) than the afternoon session.
- Temperature, precipitation and visitor numbers showed no significant effect on the count of locomotion ($F=0.16$, $P>0.05$, $F=1.81$, $P>0.05$, $F=1.44$, $P>0.05$ resp.).

Locomotion mean

- There was a significant treatment effect ($F_{5,389}=31.10$, $P<0.001$)
- The C.A.E. treatment was significantly higher than all other treatments.
- The enrichment treatment was significantly lower than all other treatments.
- Temperature and visitor numbers showed significant effects on mean locomotion ($F_{1,389}=10.14$, $P<0.005$, $F_{1,389}=8.69$, $P<0.005$).
- Precipitation and time showed no significant effect ($F=2.57$, $P>0.05$, $F=0.34$, $P>0.05$ resp.)

Resting count

- There was a significant treatment effect ($F_{5,389}=29.56$, $P<0.001$).
- C.A.E. and C.I.B.2 treatments were significantly lower than C.I.B.1 and U.A.E. treatments and significantly higher than enrichment and C.I.B.3 treatments.
- The enrichment treatment was significantly higher than the C.I.B.3 treatment.
- Precipitation showed a significant effect ($F_{1,389}=4.75$, $P<0.030$) on resting count. Temperature, visitor numbers and time (a.m./ p.m.) showed no significant effect ($F=2.81$, $P>0.05$, $F=0.14$, $P>0.05$, $F=2.41$, $P>0.05$ resp.).

Resting duration

- Significant treatment effect for the duration of resting ($F_{5,389}=11.29$, $P<0.001$).
- No significant difference between C.A.E., C.I.B.1 and U.A.E treatments.
- The enrichment and C.I.B.3 treatments were not significantly different from one another, but were significantly lower than all other treatments.
- Temperature, precipitation, visitor numbers and time of feed showed no significant effect on the duration of resting ($F=2.96$, $P>0.05$; $F=0.5$, $P>0.05$; $F=0.06$, $P>0.05$; $F=0.67$, $P>0.05$ resp.)

Appendix 9

Pictures of the new capuchin enclosure at Willowbank Wildlife Reserve.

Pictures of the new capuchin enclosure at Willowbank Wildlife Reserve.



The capuchins new outside enclosure at Willowbank Wildlife Reserve.



The capuchins new night den at Willowbank Wildlife Reserve.